

Book Version of the PhD Thesis submitted to
Dr MGR Educational and Research Institute

**AN EXPERIMENTAL STUDY ON VIRTUAL REALITY AS A PEDAGOGICAL
TOOL IN LEARNING THE SUBJECT RESPIRATORY SYSTEM
AMONG MIDDLE SCHOOL STUDENTS IN CHENNAI**



Department of Visual Communication and Animation



Dr. M.G.R.
EDUCATIONAL AND RESEARCH INSTITUTE
DEEMED TO BE UNIVERSITY

University with Graded Autonomy Status

(An ISO 21001 : 2018 Certified Institution)

Periyar E.V.R. High Road, Maduravoyal, Chennai-95. Tamilnadu, India.



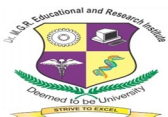
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Dr Jeevalatha J
Head & Associate Professor
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STUDENTS IN CHENNAI**

A THESIS

Submitted by

JEEVALATHA G

in partial fulfillment for the award of the degree

of

DOCTOR OF PHILOSOPHY



Department of Visual Communication and Animation

FACULTY OF HUMANITIES AND SCIENCES

Dr. M.G.R.

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(JEEVALATHA G)

ABSTRACT

Immersive technology to improve science classes was initially embraced with hopes and doubts. Teachers wondered if students habituated to chalkboards and textbooks would benefit from a virtual world where the unseen is seen. This project began with curiosity and the notion that understanding about the human body, especially the respiratory system, required more than schematics. Chennai's government middle schools, where the research was conducted, struggled to envision bronchi and alveoli. India's scientific education was mostly rote memorization, but the 2020 National Education Policy emphasized experiential and digital learning. VR allowed users to lift lungs and observe oxygen molecules travel, alveoli surrounded by capillaries and gas exchange, making abstract processes feel alive. This thesis examines whether immersion affects student learning, understanding, memory and engagement. One set of students took pre-tests in a traditional classroom, whereas others did them in immersive VR and used the VR kit. Two-month retention tests determined who had greater memory. Besides numbers, surveys measured engagement, satisfaction and learning resilience. Teachers observed behavior, experts advised, and students described their learning and overall findings were tested statistically. VR students outperformed chalk-and-board students in almost all categories. They grasped, remembered and explained topics better. With higher mean scores, VR students proved that they understood and remembered better than traditional students. Visual immersion helped VR students outperform chalk-and-board students 44% on oxyhemoglobin production. Immersion has long been shown to enhance learning in cognitive psychology. Their memories persisted two months later. Not only exam marks, but students' voices and faces. Surveys showed remarkable enthusiasm. They saw organs expand and close and saw new things. Teachers who struggled to focus restless kids noticed the shift. The participation rate was above 90%, higher than chalk-and-board sessions. Student engagement increased as quiet students asked questions and explained. VR lowered cognitive stress by reducing visual input. Animations, colors and interaction helped students to remember complex topics. Engaged and satisfied students had less cognitive strain, correlation research indicated. Peer learning thrived. Most students later discussed VR experiences with friends and many stated it helped them remember. Some felt proud to be "small teachers." These interactions cleared up misconceptions and improved knowledge, confidence and communication. VR encouraged learners to converse and collaborate after wearing headsets, supporting Vygotsky's concept that learning thrives in social situations.

Statistics highlighted Chennai's geographical inequalities. VR worked well in all three zones—north, central and south—but students in the south zone scored higher, maybe due to school infrastructure or instruction. Boys and girls benefited equally from VR, demonstrating that technology removes barriers to learning. Expert educators found that VR classrooms enhanced attention, retention and emotional participation. They also noted that mobile kits might make the technology inexpensive for wider use. Comprehensive growth and higher scores were seen. VR enhanced learning resilience, school satisfaction and science interest. Students reported feeling comfortable, invigorated and motivated to study, not bored or burdened. VR improves engagement, contentment, curiosity and peer communication, demonstrating its social and emotional benefits. VR does more than teach biology, it builds confidence, motivation and teamwork, 21st-century abilities. Multiple regression analysis indicated that these traits were linked with post-test performance. Consider limitations when reflecting on this encounter. Without clear images, VR proved less useful for abstract biochemical processes, requiring teacher intervention. Financial and technical limits persist, and the study concentrated on one city's short-term benefits. Despite these problems, VR is a powerful tool that brings subjects to life like no whiteboard. Thesis ends with a new perspective. It shows VR can make scientific classes fun and memorable. It reveals that immersive learning helps students understand, remember and share complex material. It recommends governments include VR in curricula, EdTech producers to localize content in regional languages and teachers to use it for teaching. Most importantly, it indicates that Chennai government middle school students-children with everyday desires and challenges—are willing to study if given the chance. Their excited voices about VR classes promise a new era of learning, overcoming problems and growing together. Statistics, ideas and opinions concur that VR is more than technology—it's an engaging, inclusive and future-ready learning platform. This thesis outlines an experiment's academic results and how students learnt that studying may be an experience that makes them breathe deeply into material, like their lungs do.

Keywords: Virtual Reality(VR), Chalk & Board, Understanding, Retention, Cognitive Load, Student Engagement, Learning Resilience, Student Satisfaction, Learning Interests, Peer Interaction & Communication.

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List of Symbols and Abbreviations

Abbreviation	Full Form
VR	Virtual Reality
AR	Augmented Reality
ICT	Information and Communication Technology
3D	Three-Dimensional
PCK	Pedagogical Content Knowledge
STEM	Science, Technology, Engineering, and Mathematics
LMS	Learning Management System
AI	Artificial Intelligence
OER	Open Educational Resources
K-12	Kindergarten through 12th Grade
UNESCO	United Nations Educational, Scientific and Cultural Organization
CBSE	Central Board of Secondary Education
NEP	National Education Policy
MoE	Ministry of Education (India)
VRSE	Virtual Reality Science Education
HCI	Human-Computer Interaction
WHO	World Health Organization
COVID-19	Coronavirus Disease 2019
NIH	National Institutes of Health
R&D	Research and Development
AICTE	All India Council for Technical Education
SCORM	Sharable Content Object Reference Model
ISRO	Indian Space Research Organisation
NCERT	National Council of Educational Research and Training
GCSE	General Certificate of Secondary Education (UK)

Abbreviation	Full Form
IQAC	Internal Quality Assurance Cell
NIE	National Institute of Education
VRLE	Virtual Reality Learning Environment
UGC	University Grants Commission
BYOD	Bring Your Own Device
STEAM	Science, Technology, Engineering, Arts, and Mathematics
HMD	Head-Mounted Display
FGD	Focus Group Discussion
NCERT	National Council of Educational Research and Training
CBSE	Central Board of Secondary Education
MCQ	Multiple Choice Question
HMD	Head-Mounted Display
ANOVA	Analysis of Variance
ANCOVA	Analysis of Covariance
SPSS	Statistical Package for the Social Sciences
SD	Standard Deviation
M	Mean
N	Sample Size
df	Degrees of Freedom
α	Significance Level (Alpha)
p-value	Probability Value
d	Cohen's d (Effect Size)
VRML	Virtual Reality Modeling Language
AR	Augmented Reality
LMS	Learning Management System

Abbreviation	Full Form
OECD	Organisation for Economic Co-operation and Development
3D	Three-Dimensional
SCORM	Sharable Content Object Reference Model
ROI	Return on Investment
IEP	Individualized Education Program
APA	American Psychological Association

CHAPTER 1

INTRODUCTION

1.1 Overview

The integration of Virtual Reality (VR) in education has transformed traditional pedagogical methods, especially in science learning. This study investigates the effectiveness of VR in teaching the respiratory system to government middle school students in Chennai. It explores how immersive technology can enhance understanding, retention level, engagement and peer learning. Grounded in cognitive, constructivist and experiential learning theories, the research addresses the advantages and challenges through digital innovation. The findings aim to contribute to effective science pedagogy in Indian classrooms.

1.2 Background of the Study

Science education, particularly in human anatomy and physiology, demands a learning approach that fosters conceptual clarity and experiential engagement. Traditional classroom settings often struggle to bridge the gap between abstract biological processes and student understanding, especially real time experiences (Villena-Taranilla et al., 2025). The respiratory system, with its complex structures and functions, is one such topic that middle school students find particularly difficult to grasp (Jiang et al., 2022). Pedagogical innovation is, therefore, essential to improve comprehension and retention among learners.

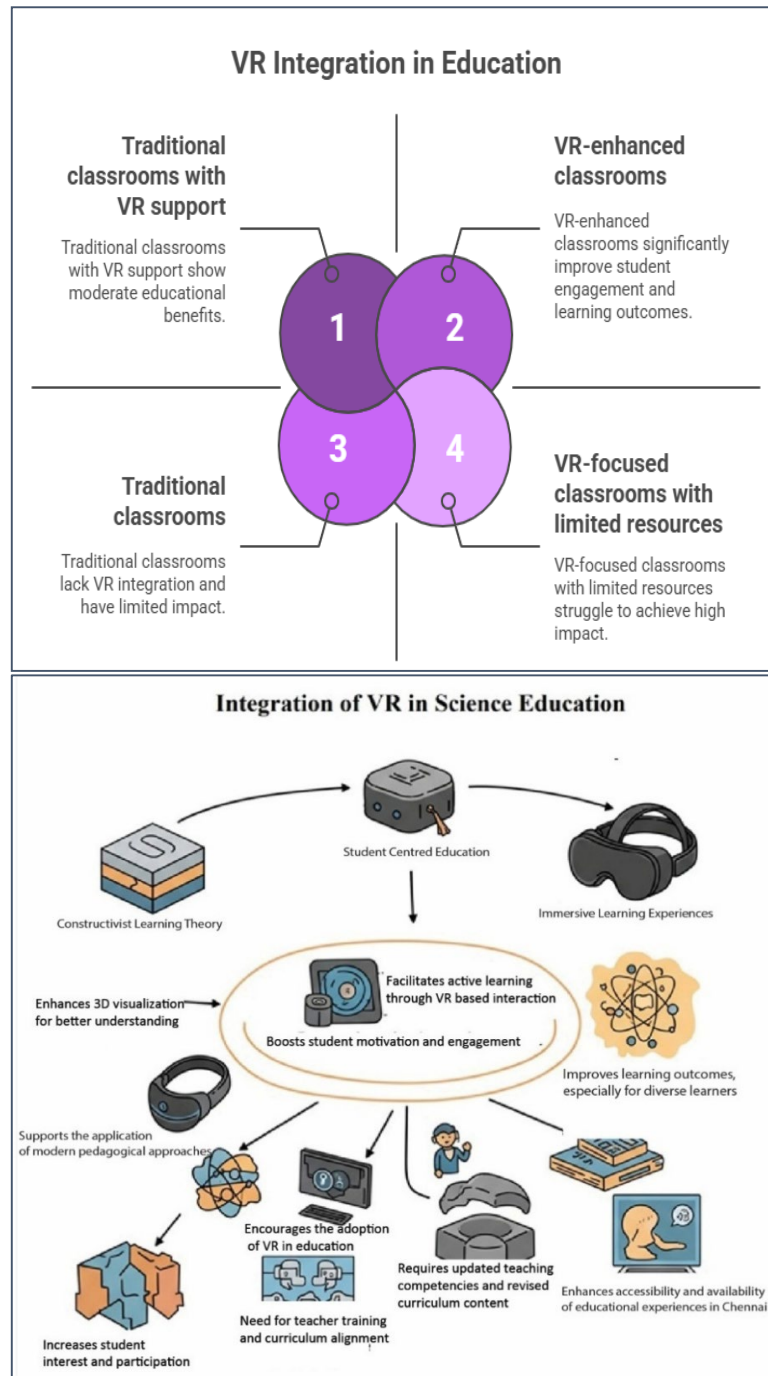


Fig. 1.1 VR Integration in Education & Science Education

Virtual Reality (VR) presents an immersive environment that can simulate real-world biological processes in 3D, making it a compelling tool for education. VR's application in pedagogy has gained attention globally as it enhances students' interaction, visualization and engagement (Hamilton et al., 2020; Maroungkas et al., 2024). The immersive nature of VR allows learners to explore anatomical systems in ways that traditional textbooks or static images cannot offer. Students can observe the inhalation and exhalation processes, identify

lung structures and understand gas exchange mechanisms through VR simulations (Schmid, K., et al. 2021)

Studies have shown that when learners interact with VR-based environments, their academic achievement and interest in science topics significantly improve (Castro et al., 2023; Saat et al., 2022). Particularly, VR has been effective in teaching complex subjects like cardiopulmonary physiology and neuroanatomy at various academic levels, from elementary to tertiary education (Hsu et al., 2025; Newton & Annetta, 2024). In India, however, the incorporation of VR in middle school classrooms remains limited due to infrastructural and economic barriers. Yet, the rapid growth of digital education, post-COVID-19 presents a timely opportunity to explore VR as a transformative pedagogical tool (Kim et al., 2022).

Chennai being a metropolitan area, middle school science education largely relies on blackboard teaching and printed visuals, which restrict multisensory learning (Pradana, 2023). This gap in experiential pedagogy calls for experimental approaches that align with 21st-century learning skills. International models from Singapore, the UK and South Korea have already demonstrated the viability of integrating VR into science curricula with promising outcomes in student comprehension, participation and long-term memory retention (Won et al., 2023).

This research study is anchored in the constructivist learning paradigm, where learners build knowledge through active engagement. By deploying VR headsets in Chennai government schools, this study investigates the feasibility, effectiveness, understanding, retention level and student reception of using VR to teach the respiratory system. The findings are expected to serve as a model for scaling up VR-assisted instruction in other schools across India. Furthermore, it adds to the growing global discourse on EdTech-enhanced pedagogy, contributing valuable insights specific to the Indian context.

1.3 Need for Innovative Pedagogical Tools in Science Education

The landscape of science education has undergone significant transformation in recent decades, propelled by technological advancements and pedagogical research. However, conventional instructional methods such as rote memorization, textbook-centric learning and one-way lecturing remain predominant in many Indian classrooms, particularly at the middle school level (Jamil, Baiduri, & Pratiwi, 2022). These methods often fail to cultivate critical thinking,

scientific reasoning and conceptual understanding, especially in subjects involving dynamic biological systems like respiration (Aytekin & Topçu, 2024).



Fig. 1.2 Steps to Integrate VR in Science Education

According to Piaget (1972) students, particularly at the adolescent level, learn best through visual support though they can handle abstraction. The complexity of human physiological processes—such as gas exchange, oxygen transport and alveolar functions—makes traditional chalk-and-talk approaches insufficient for deep learning. This has prompted educators to seek innovative pedagogical tools that align with the principles of experiential and inquiry-based learning (Hamilton et al., 2020).

Globally, there is a growing consensus that educational innovation must extend beyond digital content delivery to include interactivity, immersion and simulation (Wang et al., 2023). Innovative tools such as augmented reality (AR), game-based learning platforms and virtual laboratories have shown promising outcomes in science education (Xu et al., 2022; Rong & Yu, 2022). Among these, Virtual Reality (VR) stands out as a transformative technology that

allows students to engage directly with simulated environments, offering a sense of spatial awareness and physical interaction with otherwise invisible biological processes (Maroukhas et al., 2024).

Incorporating VR into science education fosters curiosity and enthusiasm, improves comprehension and bridges the theory-practice gap (Zhang & Wang, 2021). For instance, studies have shown that VR-enhanced teaching significantly increases student motivation, knowledge retention and classroom participation in topics such as anatomy, ecology and cellular biology (Saat et al., 2022; Newton & Annetta, 2024). These benefits are particularly relevant for middle school students, whose cognitive development thrives on visual-spatial stimulation and immediate feedback (Li & Taber, 2022; Widiana & Prayitno, 2024).

In the Indian context, the National Education Policy (NEP) 2020 underscores the importance of leveraging technology to enhance learning outcomes, encouraging schools to adopt interactive and inclusive teaching strategies (Ministry of Education, 2020). Despite this policy push, implementation remains limited due to inadequate infrastructure, teacher training gaps and lack of awareness about educational technology's pedagogical value (Koreneva et al., 2023). Addressing these challenges necessitates empirical research to evaluate innovative tools like VR in real classroom settings.

This study aims to fill that gap by experimentally testing VR's effectiveness in teaching the respiratory system to middle school students in Chennai. As India strives toward a digitally empowered education ecosystem, evidence-based models of technological integration in science education are crucial. Through immersive learning experiences, VR offers the potential not just to deliver information but to reshape how students understand and internalize scientific knowledge.

1.4 The Role of Virtual Reality in Education

Virtual Reality (VR) has emerged as a transformative educational tool, offering learners immersive experiences that are difficult or impossible to replicate in traditional classrooms. Rooted in constructivist and experiential learning theories, VR allows students to engage with educational content through interaction, simulation and real-time feedback (Maroukhas et al., 2023; Hamilton et al., 2020). In educational environments, VR's value lies in its ability to place students at the center of their learning, enabling active exploration of complex systems such as

the human respiratory system, which involves intricate anatomy and physiological mechanisms (Elharbaoui et al., 2025).

The use of VR in education has expanded dramatically across disciplines such as medical sciences, biology, physics and environmental studies. Research consistently demonstrates that VR improves students' learning outcomes, attention span, engagement and retention of knowledge (Maroungkas et al., 2024; Villena-Taranilla et al., 2025). A study by Zhao et al. (2023) emphasized that immersive environments increase student motivation by providing contextualized and lifelike scenarios, leading to deeper understanding. Similarly, Won et al. (2023) found that students exposed to VR in biology classrooms showed significantly higher conceptual understanding and problem-solving skills than those using traditional methods.

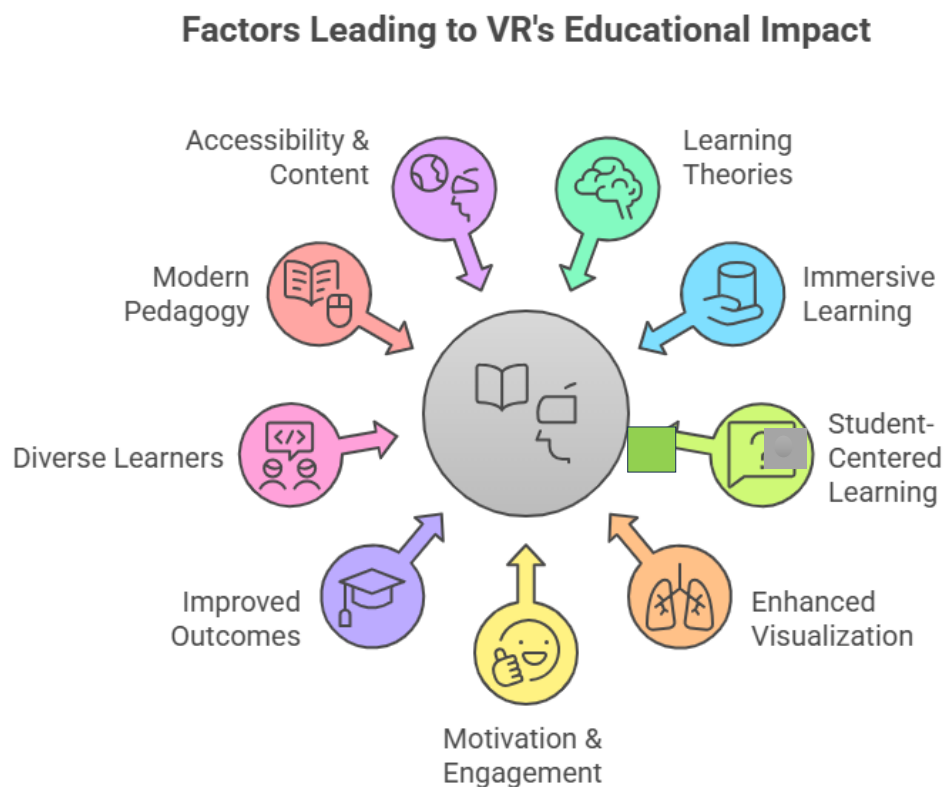


Fig.1.3 Factors Leading to VR's Educational Impact

In science education specifically, VR offers distinct advantages. Biological systems such as the respiratory system can be visualized in three dimensions, with real-time animation depicting airflow, gas exchange and diaphragm movement. This allows students to experience processes that are otherwise abstract or invisible (Hsu et al., 2025; Newton & Annetta, 2024). For middle

school learners, who are at a developmental stage where concrete visual stimuli enhance cognition, VR can bridge the gap between theory and tangible understanding (Koca & Çevik Özdemir, 2025).

VR also supports differentiated learning by allowing students to control the pace and direction of their learning, revisiting concepts as needed. Studies by Kim et al. (2022) and Aytekin and Topçu (2024) indicate that students with diverse learning needs—such as those with attention disorders or low academic motivation—benefit significantly from VR-based instruction. Moreover, educators have reported improved classroom dynamics and reduced behavioral issues when VR is used, due to heightened student immersion and engagement (Castro et al., 2023; Jamil et al., 2022).

From a pedagogical standpoint, VR aligns well with inquiry-based, constructivist and flipped classroom models. Esmaeeli et al. (2025) developed a framework showing how VR can scaffold scientific inquiry through observation, hypothesis generation, experimentation and analysis—processes integral to science education. This supports the findings of Faria and Miranda (2023), who argue that VR fosters active learning and metacognitive skills.

Despite its promise, the adoption of VR in schools remains uneven. Barriers such as cost, teacher training and curriculum alignment have slowed integration, particularly in developing countries (Li & Taber, 2022). However, with increasing affordability of VR headsets and the proliferation of educational VR content, there is a growing opportunity to mainstream VR in classrooms (Pradana, 2023; Saat et al., 2022).

In conclusion, VR stands at the frontier of educational innovation, offering students an interactive, immersive and personalized learning experience. In science education, its role is particularly potent, transforming how learners visualize, interact with and understand complex systems such as the respiratory system. This study leverages VR's potential to evaluate its effectiveness in real-time classroom application among middle school students in Chennai.

1.5 Challenges in Teaching the Respiratory System to Middle School Students

The respiratory system is a cornerstone of middle school science curricula, forming the foundation for understanding human physiology. However, educators often encounter several challenges in effectively teaching this topic, primarily due to its abstract nature, intricate

processes and the limited availability of visual aids in traditional classrooms (Aytekin & Topçu, 2024). The core concepts—such as gas exchange, oxygen transport, alveolar diffusion and the diaphragm’s mechanics—are complex and not directly observable, making it difficult for students to internalize through textbooks alone (Gaylan et al., 2024).

Cognitive development theories suggest that middle school students are transitioning from concrete operational thinking to formal operational thought, meaning they can struggle with abstract reasoning if not supported by visual or experiential stimuli (Li & Taber, 2022). The lack of real-world visualization in teaching the respiratory system can hinder students' conceptual understanding and lead to rote memorization, which does not support long-term retention or application (Hadad et al., 2025). According to Widiananda and Prayitno (2024), the inability to visualize internal body systems contributes to persistent misconceptions, such as confusing breathing with respiration or misunderstanding the function of alveoli.

Furthermore, science teachers often lack the resources or training necessary to translate complex anatomical concepts into engaging classroom activities. Many schools in India, particularly in urban public or semi-private settings, are constrained by inadequate infrastructure, large class sizes and rigid curricula that emphasize exam-oriented learning (Koreneva et al., 2023; Pradana, 2023). Teachers often rely on static diagrams, lectures and textbook explanations that fail to capture students’ attention or stimulate inquiry (Newton & Annetta, 2024).

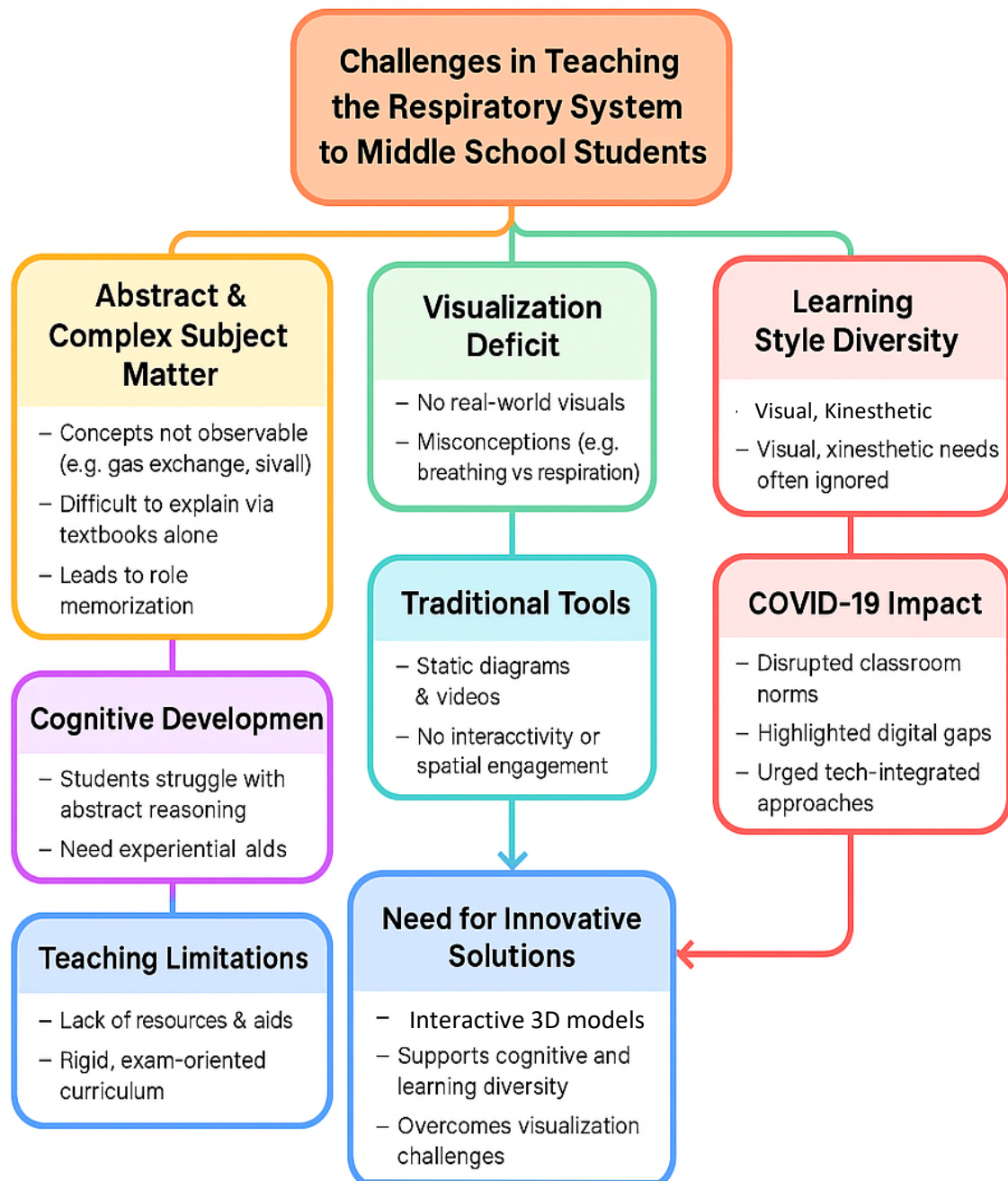


Fig. 1.4 Challenges in Teaching the Respiratory System to Middle School Students

Additionally, students' varying learning styles and prior knowledge further complicate instruction. While some learners may grasp concepts through verbal explanations, others require visual, kinesthetic, or experiential modes to understand deeply. However, the traditional science classroom rarely accommodates these differences (Villena-Taranilla et al., 2025). Elharbaoui et al. (2025) reported that even in well-equipped environments, the lack of dynamic teaching tools results in superficial learning outcomes in respiratory system education.

Technological interventions such as video animations and models have attempted to bridge this gap, but they often lack interactivity and immersion (Hsu et al., 2025; Zhao et al., 2023). For instance, a 2D video showing lung expansion may demonstrate the mechanics but cannot provide the student with a spatial understanding or hands-on interaction with the structures involved. This lack of embodiment—where students physically or virtually experience the learning content—limits the effectiveness of traditional multimedia (Rong & Yu, 2022).

Moreover, the COVID-19 pandemic disrupted conventional classroom teaching, exposing systemic vulnerabilities in science education delivery and highlighting the urgency for innovative approaches (Kim et al., 2022). With increasing digital literacy and access to mobile technologies, educational systems now have a unique opportunity to integrate more immersive tools such as Virtual Reality.

Given these pedagogical and infrastructural challenges, it becomes imperative to evaluate new approaches like VR that can overcome the limitations of traditional teaching. By providing 3D, interactive and context-rich simulations of the respiratory system, VR has the potential to address core instructional difficulties while aligning with students' cognitive needs.

1.6 Advantages of Using VR in Science Classrooms

The incorporation of Virtual Reality (VR) into science classrooms represents a paradigm shift in how scientific knowledge is delivered, comprehended and retained. Particularly in complex domains such as biology and physiology, VR transforms passive learning into an active, immersive and interactive experience (Hamilton et al., 2020; Villena-Taranilla et al., 2025). Technology allows students to navigate through microscopic structures, simulate biological processes and manipulate virtual models in real-time, enhancing both conceptual understanding and learner motivation.

One of the primary advantages of VR in science education is **spatial visualization**. The human respiratory system, with its intricate structures like alveoli, bronchioles and diaphragmatic movement, can be difficult to visualize using traditional 2D diagrams. VR addresses this by rendering 3D models that students can explore from multiple perspectives, thereby developing a spatial and functional understanding of anatomical components (Esmaeeli et al., 2025). As Kablitz (2025) note, this immersive visualization bridges the gap between theoretical knowledge and real-world understanding.

Another significant benefit is **experiential learning**. VR provides a virtual environment where learners can simulate breathing processes, monitor gas exchange and visualize oxygen flow into tissues. This active involvement leads to improved knowledge retention compared to traditional methods such as lectures or textbook reading (Koca & Çevik Özdemir, 2025; Rong & Yu, 2022). Studies by Saat et al. (2022) and Hsu et al. (2025) indicate that students taught using VR demonstrated higher Post Test scores and more accurate recall of physiological concepts.

VR also enhances learner engagement and motivation, especially for students who may find biology abstract or challenging. The gamified and interactive nature of VR appeals to digital-native learners, stimulating interest and reducing science anxiety (Newton & Annetta, 2024). Research by Pradana (2023) found that middle school students exposed to VR science modules were more likely to participate in class discussions, ask questions and complete assignments with greater enthusiasm.

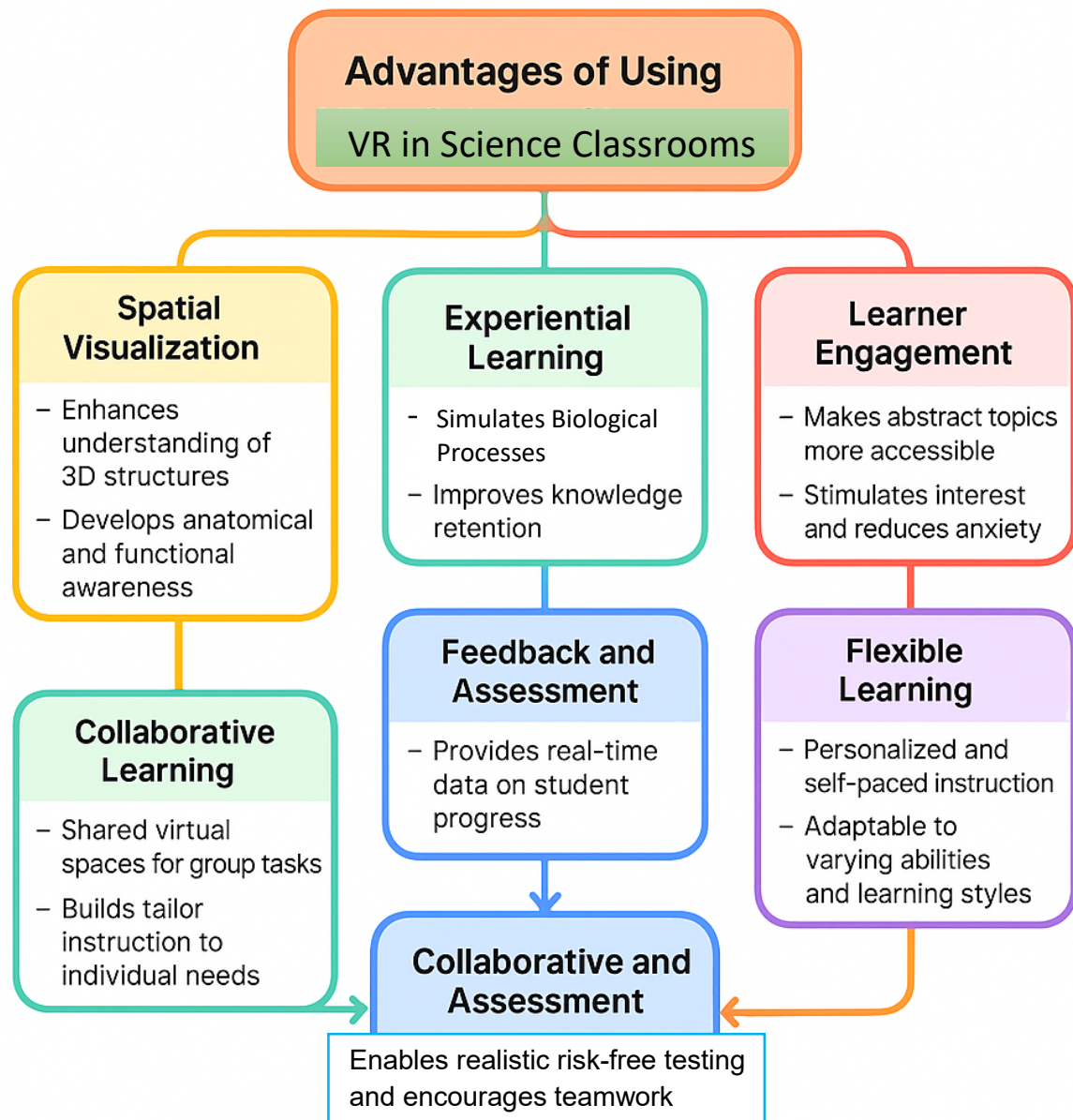


Fig. 1.5 Advantages of Using VR in Science Classrooms

Moreover, VR supports personalized and self-paced learning. Unlike conventional classroom settings, VR platforms often allow students to revisit modules, repeat simulations and explore content based on individual learning needs (Aytekin & Topçu, 2024; Li & Taber, 2022). This adaptability is particularly beneficial in inclusive classrooms, where students may vary in their cognitive abilities and prior knowledge.

Additionally, VR encourages collaborative learning through shared virtual spaces where students can interact, discuss and solve problems together which supports skills such as communication, critical thinking and teamwork (Fargo, 2013). Teachers also benefit from real-

time feedback and assessment tools integrated into many VR systems, allowing them to track student progress and tailor instruction accordingly (Kim et al., 2022).

Importantly, the use of VR aligns with national educational goals in India. The National Education Policy (NEP) 2020 advocates technological integration in classrooms to promote creativity and inquiry-based learning (Ministry of Education, 2020). Thus, adopting VR not only enhances learning outcomes but also advances educational policy implementation.

In summary, VR in science classrooms enables visual, experiential, engaging and flexible learning. It addresses pedagogical gaps, accommodates diverse learners and fosters an active learning culture an essential step forward for Indian middle school education, especially in subjects like the respiratory system.

1.7 Educational Landscape in Chennai's Middle Schools

Chennai, the capital city of Tamil Nadu, is known for its rich educational heritage and a high literacy rate compared to other Indian metropolitan areas. The city houses a wide range of educational institutions, including government schools, aided private schools and unaided private institutions. While Chennai's middle schools are progressive in some aspects of pedagogy, the integration of educational technology, especially immersive tools like Virtual Reality (VR) remains limited and inconsistent (Pradana, 2023; Koreneva et al., 2023).

The Tamil Nadu State Board syllabus, which governs a large proportion of middle schools in Chennai, places considerable emphasis on factual recall and board examination performance, often at the cost of conceptual understanding and experiential learning. Teaching of subjects like science tends to be textbook-driven and practical demonstrations are usually confined to higher secondary levels (Faria & Miranda, 2023). This has resulted in middle school students receiving minimal hands-on exposure to the intricacies of biological systems such as the respiratory system (Aytekin & Topçu, 2024).

Despite the availability of digital resources through initiatives like the Tamil Nadu ICT Policy and schemes like Samagra Shiksha, the adoption of educational technologies varies significantly across institutions. While some elite private schools have invested in smart classrooms and digital content platforms, government and budget private schools continue to rely on conventional pedagogical approaches due to financial and infrastructural constraints (Marougkas et al., 2024). This digital divide not only limits access to immersive learning tools

like VR but also contributes to disparities in learning outcomes among students from different socioeconomic backgrounds.

Teacher readiness is another major hurdle. While the state government has initiated teacher training programs in digital pedagogy, most middle school teachers in Chennai have limited exposure to immersive technologies such as VR or AR (Zhang & Wang, 2021). According to studies by Jamil, Baiduri and Pratiwi (2022), teachers express concerns about the feasibility of integrating VR tools into their existing curriculum, citing a lack of time, training and technical support. Furthermore, many educators are unfamiliar with the instructional design principles required for effective use of VR in lesson planning (Kim et al., 2022; Villena-Taranilla et al., 2025).

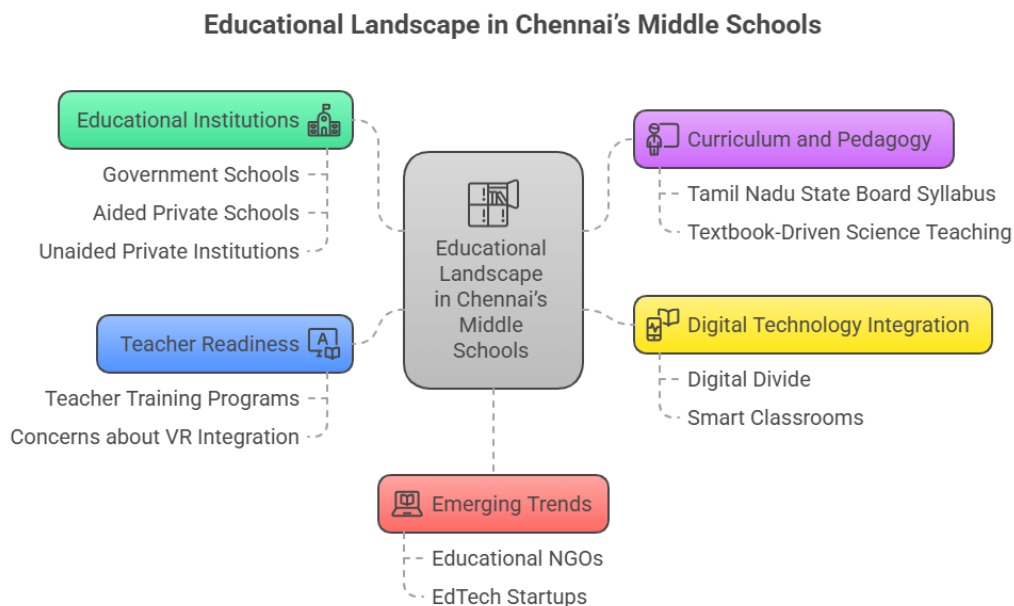


Fig. 1.6 Educational Landscape in Chennai's Middle School

Fig. 1.6 shows the educational landscapes in Chennai's middle school which describes about Digital Technology Integration, types of Educational Institutions, current pedagogy used in Tamil Nadu middle schools and the emerging trends. However, there is an emerging trend among educational NGOs and EdTech startups in Chennai to introduce low-cost, modular VR systems in selecting urban and semi-urban schools as pilot projects. These interventions have shown promise in enhancing student engagement and learning outcomes, especially in science topics that benefit from visual and interactive explanations (Esmaeeli et al., 2025). For instance, immersive modules designed for anatomy and ecosystem simulations have been well-received

in middle school environments, demonstrating the technology's relevance and potential (Newton & Annetta, 2024).

Given Chennai's urban infrastructure, high digital penetration and educationally aware population, the city is uniquely positioned to become a model for VR integration in Indian middle school education. However, this requires coordinated efforts in teacher training, resource allocation, curriculum alignment and policy advocacy (Saat et al., 2022; Rong & Yu, 2022).

Finally, while Chennai's middle schools offer a strong academic foundation, there remains a clear need to enhance science pedagogy through immersive, interactive technologies like VR. This study seeks to explore that opportunity by evaluating the implementation of VR-based instruction for the respiratory system among middle school students in Chennai.

1.8 Significance of the Study in the Indian Context

In recent years, India's education sector has undergone considerable policy reform aimed at integrating digital tools into classrooms. The **National Education Policy (NEP) 2020** envisions a technology-driven pedagogy that fosters critical thinking, creativity and experiential learning (Ministry of Education, 2020). Yet, the practical application of these reforms in middle school science education remains limited, especially when it comes to the use of immersive technologies like Virtual Reality (VR). This study addresses this gap by exploring the potential of VR as a pedagogical tool for teaching the respiratory system—a crucial yet abstract subject—in Indian classrooms, specifically in Chennai.

Science education in India traditionally emphasizes textbook-based instruction, with assessments focused on rote memorization rather than conceptual understanding or real-world application (Kim et al., 2022). This has been a significant challenge in subjects such as biology and physiology, where concepts like gas exchange or lung capacity are difficult to comprehend without visual or practical demonstration (Aytekin & Topçu, 2024). In this context, VR can offer a revolutionary alternative. It enables students to immerse themselves in biological systems, visualizing and manipulating virtual organs and processes, thereby fostering deeper understanding (Hsu et al., 2025).

The Indian context also presents unique socio-economic and infrastructural challenges. While the urban population increasingly has access to smartphones and broadband internet, schools

in both urban and semi-urban areas still face disparities in technological readiness (Koreneva et al., 2023; Jamil, Baiduri, & Pratiwi, 2022). By focusing on Chennai—a major metropolitan city with a mix of high-performing private schools and under-resourced public institutions—this study offers valuable insights into the scalability and adaptability of VR-based instruction in diverse educational environments.

Moreover, the **respiratory system** has public health relevance in India. Issues such as pollution, asthma and tuberculosis make understanding respiratory health not just a biological necessity but a societal imperative. Teaching students about the respiratory system through immersive technology could enhance health awareness from a young age (Newton & Annetta, 2024). This study, therefore, intersects education and public health, making it highly relevant in the Indian socio-educational landscape.

India's emerging EdTech sector provides additional motivation for this research. Numerous Indian startups are developing VR applications for education, but few are empirically tested in real classroom settings. This study provides a much-needed evidence base to assess VR's effectiveness in enhancing student learning outcomes in Indian schools (Rong & Yu, 2022). The findings could inform educators, policymakers and technologists in developing curriculum-aligned VR content tailored to Indian learners.

Furthermore, the research aligns with **United Nations Sustainable Development Goal 4**, which calls for inclusive and equitable quality education and lifelong learning opportunities for all (UNESCO, 2020). VR holds potential as an equalizer, offering high-quality science education even in resource-constrained settings—provided implementation is supported through thoughtful design and policy.

In summary, this study is significant for its potential to:

- Innovate science pedagogy in Indian middle schools.
- Evaluate the real-world application of VR in classrooms.
- Contributes to policy discussions on digital learning.
- Enhance health literacy among school students.
- Offer scalable solutions for diverse educational contexts in India.

1.9 Research Gap and Justification

Despite the increasing global interest in immersive technologies for education, a critical review of existing literature reveals a notable gap in empirical studies assessing the integration of Virtual Reality (VR) into Indian middle school science classrooms—especially in the context of teaching human biology topics like the respiratory system. While studies from Europe, the U.S. and East Asia have demonstrated positive outcomes associated with VR-based learning (Hamilton et al., 2020; Villena-Taranilla et al., 2025; Maroungkas et al., 2024), research in the Indian context is still in its infancy. This gap limits the generalizability of global findings to Indian classrooms, which differ significantly in terms of instructional practices, student demographics, infrastructure and curriculum design (Jamil et al., 2022).

One key gap is the lack of content-specific VR studies focusing on subjects like the respiratory system at the middle school level. While VR applications in medical education and tertiary biology programs are widely documented (Jiang et al., 2022; Hsu et al., 2025), there is minimal research on how such tools impact foundational science learning among adolescent learners (Faria & Miranda, 2023). Given that the middle school phase (Grades 6–8) is critical for cultivating interest in STEM disciplines, ignoring this cohort in VR research limits the scope of educational innovation.

A second gap involves the absence of experimental design-based studies that evaluate learning outcomes using VR versus traditional methods. Most existing studies rely on anecdotal evidence, descriptive feedback, or qualitative perceptions without statistically validating improvements in conceptual understanding, engagement, or recall (Newton & Annetta, 2024; Widiana & Prayitno, 2024). This study fills that void by employing experimental research design, comparing student performance and engagement across a control group and an experimental group exposed to VR-assisted instruction.

There is also limited research exploring culturally and contextually appropriate deployment of VR in Indian classrooms. Much of the available VR content is designed with Western learners in mind, often misaligned with Indian syllabi, learning styles, or linguistic preferences (Koreneva et al., 2023; Li & Taber, 2022). This study adopts localized instructional design, aligning VR content with the Tamil Nadu State Board curriculum to ensure pedagogical relevance.

Furthermore, the digital divide within India presents both a research challenge and a critical point of inquiry. While a growing number of schools in metropolitan areas like Chennai are adopting smart classroom solutions, many still struggle with internet access, trained personnel and affordability (Aytekin & Topçu, 2024). By focusing on a mixed group of public and private middle schools, this research investigates VR's feasibility and adaptability in diverse educational settings, contributing to the discourse on equity and digital inclusion.

In summary, this study is justified by:

- The underrepresentation of middle school-level VR research in India.
- The lack of content-specific (e.g., respiratory system) VR studies.
- The need for robust, experimental designs to evaluate efficacy.
- The necessity to localize and align VR content with Indian curricula.
- The opportunity to examine feasibility in technologically varied school environments.

By addressing these gaps, the present research aims to generate actionable insights for educators, policymakers and EdTech developers, ultimately enhancing science education outcomes for middle school students in India.

1.10 AIM of the Study

Aim of the study is to experiment and analyse, the usage of VR as a pedagogical tool in schools in Chennai for learning the Science Subject respiratory system and to find out the understanding level, knowledge retention level among students when it is taught using VR. The research mainly focuses on examining the difference between the retention level of students when taught through traditional method of teaching when compared to the pedagogical tool VR based teaching. The analysis includes the cognitive abilities among students whether they can recollect the subject through the animation and colours that they see in VR. Additionally, the study aims to highlight the student engagement, satisfaction and interest to come to school and whether it will help to overcome learning difficulties and whether students can have a peer interaction, leading to teamwork and good communication skills.

1.11 Objectives of the Study

In the current educational landscape, the integration of immersive technologies like Virtual Reality (VR) is being recognized not merely as a supplement to traditional teaching but as a

transformative tool that redefines how learning occurs. With specific reference to science subjects such as the respiratory system, VR offers interactive, multisensory experiences that hold significant potential to address long-standing pedagogical challenges. Accordingly, this study outlines a set of clearly defined objectives that guide its design and implementation, ensuring alignment with both academic inquiry and practical classroom needs.

1. To examine the current understanding and knowledge levels of students regarding the subject taught through conventional methods when compared to the knowledge level of the students after the usage of VR.
2. To investigate the influence of virtual reality on students', knowledge retention and cognitive abilities.
3. To examine the impact of virtual reality-based teaching methods on student engagement, Learning Resilience (overcoming learning difficulties), student satisfaction, learning interest.
4. To analyse whether VR promoted Collaborative and Social Learning leading to peer interaction and the development of teamwork and communication skills.

Collectively, these objectives aim to provide a comprehensive understanding of how Virtual Reality can transform science education at the middle school level, particularly in urban Indian settings like Chennai. The findings will not only evaluate VR's pedagogical merit but also offer actionable insights for curriculum designers, EdTech developers and policymakers.

1.12 Need for the Study

The decision to focus this experimental research on the respiratory system in biology was grounded in practical insights gathered from discussions with middle school science teachers and headmasters from various schools in Chennai. These educational professionals unanimously recommended concentrating on biology over physics and chemistry, as the latter subjects already benefit from structured laboratory facilities. In contrast, biology, particularly its conceptual aspects, often lacks hands-on visualization tools in school settings.

The choice to focus on the respiratory system was further influenced by the context in which the thesis began—immediately following the COVID-19 pandemic. Given that COVID-19 is

primarily a respiratory illness, the topic of respiration was highly relevant and timely. Teachers also emphasized that students consistently struggle to visualize internal processes like airflow, gas exchange and the purification of air within the human body. Compared to other topics like the human eye, the respiratory system presented more opportunities for immersive conceptual learning using virtual tools.

In addition, a preliminary study using 3D animation of the respiratory system was conducted to identify specific conceptual hurdles faced by students. The data collected from this activity was analyzed and the insights were directly incorporated into the design and focus of the present thesis, strengthening its relevance and applicability.

1.13 Scope of the Study

This study explores the effectiveness of Virtual Reality (VR) as a teaching tool for the respiratory system among middle school students in Chennai. Traditional science education often fails to engage students or clarify complex concepts like respiration. VR provides immersive, 3D learning experiences that enhance understanding, retention and student motivation. The research is grounded in constructivist and experiential learning theories and addresses gaps in India's digital education implementation. It compares outcomes between conventional and VR-based teaching using an experimental design. The study assesses engagement, knowledge acquisition, retention, critical thinking and collaborative learning. Focused on students in grades 6–8, it aligns content with the Tamil Nadu State Board syllabus. Though limited to urban Chennai and short-term impacts, the findings have implications for scaling VR in Indian classrooms. The research contributes to policy, curriculum development and educational technology innovation. Ultimately, it demonstrates how VR can transform science learning into an interactive and impactful experience.

1.14 Chapterization

The structure of this study is organized into clearly defined chapters that progressively build the foundation, execution and interpretation of the research. The **chapterization** follows a logical flow from conceptual framework to data analysis and conclusions, reflecting the mixed-method experimental approach adopted in evaluating Virtual Reality (VR) as a pedagogical tool for teaching the respiratory system to middle school students in Chennai.

1.14.1 Chapter 1: Introduction

This chapter lays the groundwork for the study by outlining the context, rationale and scope of the research. It details the background of the problem, the need for innovative teaching approaches and the relevance of VR in middle school science education. It also articulates the research gap, objectives and the significance of the study in the Indian educational landscape. The chapter concludes with the structure of the dissertation.

1.14.2 Chapter 2: Review of Literature

A comprehensive review of existing research on Virtual Reality in education is provided in this chapter. It synthesizes global and Indian studies that explore the impact of VR on student engagement, knowledge retention and cognitive development (Hamilton et al., 2020; Villena-Taranilla et al., 2025). Special emphasis is placed on literature addressing the challenges of teaching the respiratory system and how immersive technologies help address these gaps. The chapter identifies theoretical frameworks such as constructivism, experiential learning and multimedia learning theory that inform the study.

1.14.3 Chapter 3: Research Methodology

This chapter outlines the research design, including the experimental structure with control and test groups. It describes the sampling procedures, research setting, VR content used and the methods for data collection and analysis. Both quantitative tools (Pre Test/Post Test, Likert scale questionnaires) and qualitative inputs (student feedback, teacher interviews) are discussed. Validity, reliability and ethical considerations are also addressed (Aytekin & Topçu, 2024; Maroungkas et al., 2024).

1.14.4 Chapter 4: Data Analysis and Interpretation

Findings from both the quantitative and qualitative components are presented and interpreted in this chapter. Statistical tests such as t-tests, paired T-tests, ANOVA and Chi-Square tests, are used to evaluate the effectiveness of VR on various learning parameters—engagement, comprehension, retention and critical thinking (Hsu et al., 2025; Widiani & Prayitno, 2024). Qualitative themes emerging from open-ended responses and teacher observations are also discussed to provide context and depth. The findings in relation to previous research and

theoretical frameworks are contextualized. The implications of the results for classroom practice, curriculum design and EdTech integration are critically examined. Barriers to VR adoption and possible solutions are explored, with specific recommendations for Indian educators and policymakers (Li & Taber, 2022).

1.14.5 Chapter 5: Findings & Conclusion

The final chapter synthesizes the overall findings, restates the contributions of the study and suggests directions for future research. Recommendations are offered for curriculum designers, school administrators and educational technology developers, particularly in resource-constrained Indian school systems. Limitations of the study are also acknowledged.

This structured chapter plan ensures that the study progresses cohesively from theory to practical findings and policy implications. Each chapter contributes to answering the central research question: How effective is Virtual Reality in enhancing middle school students' learning of the respiratory system?

1.15 IMPLICATIONS

This study has broad implications for educational policy, curriculum development and classroom practice. It highlights the potential of Virtual Reality (VR) to transform science pedagogy in Indian middle schools by enhancing conceptual clarity, engagement and cognitive development. The findings can guide school administrators in adopting immersive technologies and inform EdTech developers in creating localized, curriculum-aligned content. It also contributes to reducing the digital divide by testing scalable, low-cost VR solutions. Teachers can leverage the results for inclusive, differentiated instruction. Finally, it offers a model for integrating 21st-century skills into core science curricula.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Overview

Virtual Reality (VR) has emerged as a transformative educational tool, especially in middle school science education. It offers immersive environments that enhance visualization, engagement and conceptual understanding. Researchers globally have explored VR's pedagogical potential through cognitive, constructivist and experiential learning frameworks. Its application in biology, particularly the human respiratory system, shows promise in overcoming instructional limitations. However, integration challenges and gaps in regional implementation persist.

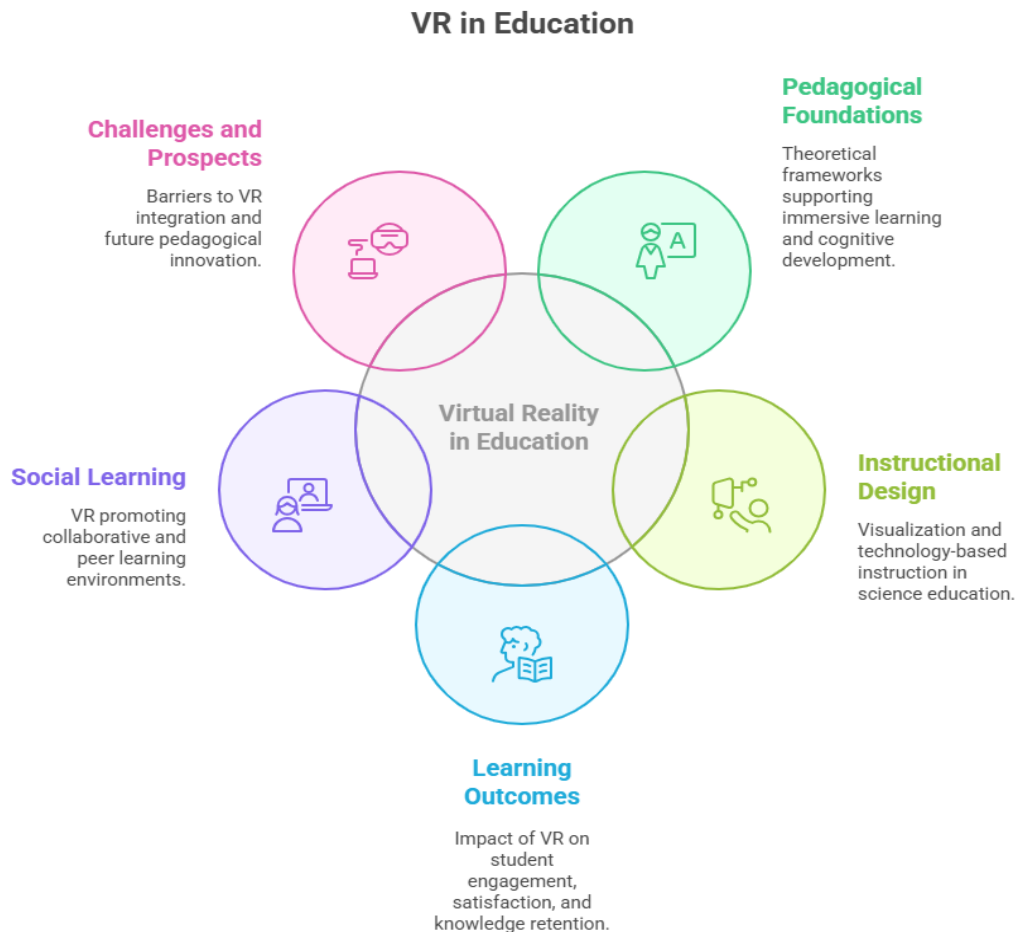


Fig. 2.1 Pedagogical Foundations of VR in Education

2.2 Introduction to Virtual Reality in Education

Virtual Reality (VR) in education leverages computer-generated simulations to provide immersive, interactive experiences, allowing learners to explore complex content beyond the confines of physical classrooms (Bailenson, 2018; Radianti et al., 2020). The entire educational experience has the potential to be revolutionized by emerging virtual reality technologies. (Zhao et al., 2023). New evidence suggests that lessons supported by Virtual Reality (VR) can improve positive emotions and engagement, as well as create more memorable experiences, when contrast with conventional instructional tools like textbook passages and videos. (Rodolico & Lavinia Hirsu, 2023). In the context of middle school science, VR provides a compelling platform to visualize abstract concepts such as cellular structures, energy systems, or respiratory mechanisms in three-dimensional environments (Liimatainen, 2021). Unlike traditional methods, VR offers experiential learning with multisensory engagement that improves student attention and motivation (Freina & Ott, 2015). One of the main benefits of virtual reality in the classroom is the ability to make engaging and interactive experiences that can mimic real-life situations so that school children can learn through experiential learning rather than just reading about it in textbooks. (Zhao et al., (2023)

Recent studies highlight how VR aligns with 21st-century educational priorities such as inquiry-based learning, collaborative exploration and learner autonomy (Southgate et al., 2019; Jensen & Konradsen, 2018). Schools worldwide have begun adopting VR for biology, chemistry and physics instruction, reporting improvements in student comprehension, critical thinking and retention (Papanastasiou et al., 2019). In particular, applications like zSpace, ClassVR and CoSpaces Edu are tailored for middle school environments, integrating curriculum objectives with immersive content (Ghergulescu & Muntean, 2021).

The proliferation of low-cost VR headsets (e.g., Oculus Quest, Google Cardboard) and curriculum-aligned apps has further facilitated VR integration (Wu et al., 2021). However, the literature also recognizes disparities in access, lack of teacher training and curriculum alignment as persisting challenges (Parong & Mayer, 2018; Bower et al., 2020). Thus, VR's potential remains both promising and contingent on systemic readiness.

2.3 Theoretical Frameworks Supporting Immersive Learning

Theoretical foundations for immersive learning through Virtual Reality (VR) are primarily rooted in constructivist, social constructivist and cognitive learning theories. VR aligns with Piaget's constructivism, which emphasizes active knowledge construction through experience (Piaget, 1972). In immersive environments, learners interact with dynamic simulations, enabling them to construct meaning rather than passively receive information (Bricken, 1991; Dede, 2009). Vygotsky's social constructivism further supports VR's collaborative features, highlighting the role of social interaction and scaffolding in knowledge acquisition (Vygotsky, 1978).

Situated Learning Theory (Lave & Wenger, 1991) also complements VR integration, as it allows learners to engage in contextually rich tasks mirroring real-world environments. This is particularly vital for subjects like human biology, where VR can simulate organ systems or cellular processes (Radianti et al., 2020). Cognitive Load Theory (Sweller, 1988) is frequently cited in VR research to justify how immersive experiences reduce extraneous load and enhance schema construction (Parong & Mayer, 2018).

Recent VR-based studies apply these theories to design effective learning interventions. Shamseieh and Mousa (2024) observed increased motivation and cognitive processing when students learned science concepts through VR. Similarly, OcuLeO, an immersive VR project, utilized digital storytelling to improve conceptual clarity (Sasso et al., 2024).

In summary, VR-based learning is theoretically well-grounded, providing a bridge between experiential, cognitive and social learning frameworks.

2.4 Constructivist and Experiential Learning through VR

Virtual Reality (VR) is fundamentally aligned with constructivist and experiential learning theories, both of which emphasize the learner's active role in building knowledge through interaction, reflection and context. Constructivism posits that knowledge is constructed through engagement with the environment, not passively absorbed (Jonassen, 1999; Piaget, 1972). VR offers a safe, controlled and immersive environment where learners can experiment, fail and reflect—key tenets of experiential learning (Kolb, 1984).

Kolb’s Experiential Learning Cycle—comprising concrete experience, reflective observation, abstract conceptualization and active experimentation—is vividly realized in VR platforms that allow learners to explore systems like the human body or atomic structures in real-time (Kant et al., 2019). These experiences encourage deep learning, critical thinking and the integration of new knowledge with existing cognitive structures (Brown et al., 1989). For example, learners using VR to dissect a virtual frog engage directly with the process, reflect on biological functions and reapply the knowledge in problem-solving scenarios (Soliman et al., 2022).

Additionally, constructivist tools like CoSpaces Edu and zSpace enable learner-centered creation, promoting agency and personalization in science education (Ghergulescu & Muntean, 2021). Studies such as those by Sasso et al. (2024) and Singh et al. (2024) show that VR applications rooted in constructivist principles significantly enhance conceptual understanding and motivation.

Thus, the experiential and constructivist affordances of VR mark a paradigm shift from teacher-centered instruction to learner-centered exploration.

VR in Education: Theories and Challenges				
Characteristic	Constructivism	Experiential Learning	Cognitive Development	Biology Pedagogy
Definition	Knowledge built through interaction	Learning through experience and reflection	Growth in thinking and reasoning skills	Teaching abstract biological concepts
VR Support	Enables active knowledge construction	Offers safe environment for experimentation	Scaffolds abstract reasoning and analysis	Provides visualization of complex systems
Benefits	Promotes deep learning and agency	Encourages critical thinking and integration	Enhances working memory and attention	Reduces misconceptions and increases relevance
Examples	CoSpaces Edu and zSpace enable creation	Virtual frog dissection engages learners	VR anatomy simulation improves spatial reasoning	VR simulations reduce learning misconceptions

Fig. 2.2 VR in Education: Theories & Challenges

2.5 Cognitive Development in Middle School Learners

Middle school marks a critical phase in cognitive development, as learners transition from concrete to formal operational thinking (Piaget, 1972). At this stage, students begin to engage in abstract reasoning, logical analysis and hypothetical problem-solving—skills essential for mastering science concepts. Virtual Reality (VR) can scaffold these cognitive shifts by offering multisensory and spatially rich environments that stimulate higher-order thinking (Mayer et al., 2023).

Cognitive theories like Bloom’s Taxonomy and Vygotsky’s Zone of Proximal Development (ZPD) provide a framework for understanding how VR facilitates mental growth (Vygotsky, 1978; Anderson & Krathwohl, 2001). In VR environments, learners operate in their ZPD with scaffolded guidance and feedback, allowing for more effective internalization of complex scientific processes, such as respiration or photosynthesis. This is especially beneficial for learners with varying cognitive styles or learning disabilities (Abrams et al., 2024).

A study by Mu et al. (2024) on VR-based anatomy simulation found significant improvements in spatial reasoning and scientific vocabulary acquisition. Similarly, Sulisworo et al. (2024) demonstrated that cognitive load was managed effectively when students were guided through immersive VR biology modules. These findings suggest that VR not only supports cognitive development but also reduces misconceptions by providing real-time visualization and feedback.

Thus, the cognitive benefits of VR extend beyond engagement—enhancing working memory, attention and metacognitive skills essential for science mastery.

2.6 Pedagogical Challenges in Teaching Human Biology

Human biology presents unique pedagogical challenges at the middle school level due to the abstract, microscopic and often non-visible nature of the subject matter. Teachers frequently report difficulties in conveying the dynamic and systemic interactions of organs, cells and biochemical processes, such as gas exchange or respiration (Yen & Huang, 2001). Traditional textbooks and two-dimensional diagrams often fail to stimulate student interest or accurately portray biological complexity (Van Horne et al., 2012).

Another key challenge is the prevalence of misconceptions. Middle school students often harbor incorrect notions about anatomy, such as confusing the function of the lungs or misunderstanding oxygen transport (Lewis & Wood-Robinson, 2000). Furthermore, time constraints, limited lab access and varied student learning styles impede differentiated instruction (Barak et al., 2011). Teachers also encounter difficulties in making biology personally relevant to adolescents, which affects motivation and retention.

The integration of active learning strategies such as dissection is increasingly limited by ethical, logistical and health concerns, prompting a need for virtual alternatives (Makransky et al., 2020). VR offers promising solutions by immersing students in anatomical environments where they can manipulate structures, observe systems in action and engage in exploratory learning without biological hazards.

For instance, Soliman et al. (2022) demonstrated that VR simulations significantly reduced misconceptions in middle school biology, while Topalska (2024) emphasized VR's value in overcoming pedagogical inertia through technological innovation.

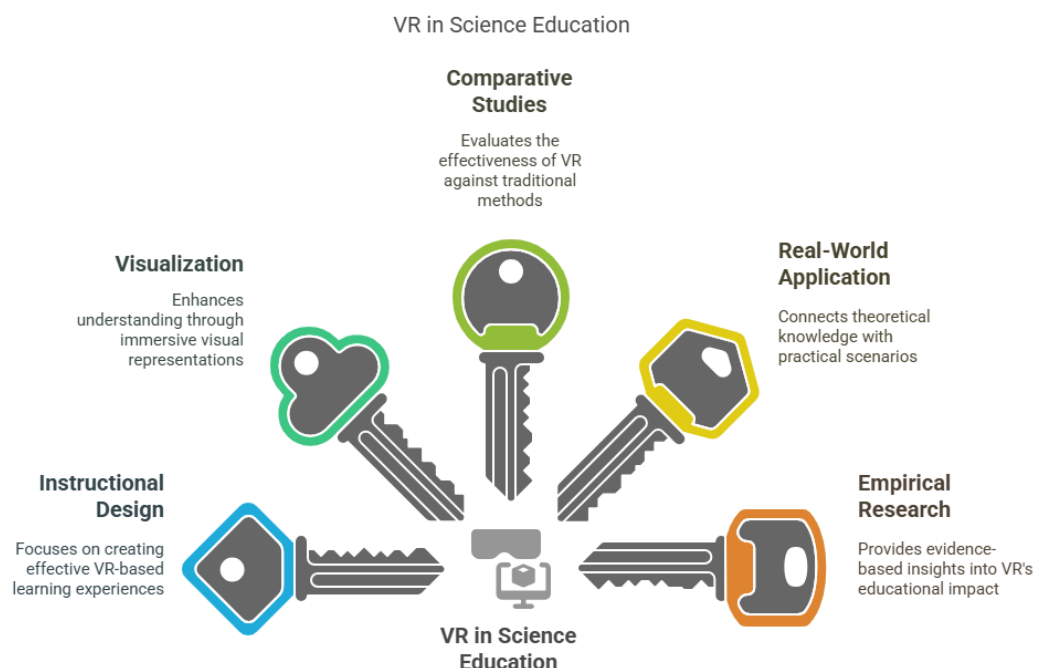


Fig. 2.3 Instructional Design and Delivery Through VR

2.7 Visualization and Understanding of the Respiratory System

The respiratory system is a central yet challenging topic in middle school biology due to its complex structure and invisible physiological processes such as gas exchange and oxygen transport. Visualization plays a crucial role in helping students grasp these mechanisms (Yip, 1998). Traditional teaching methods often rely on static diagrams, which fail to convey the dynamic interplay between organs like the lungs, trachea and alveoli, leading to misconceptions (Chi et al., 1994; Prokop & Fancovicová, 2006).

Virtual Reality (VR) provides a solution by enabling three-dimensional, immersive visualization of the respiratory system. In VR environments, people can virtually “walk through” the bronchial tree, observe gas exchange at the alveolar level and simulate breathing cycles, which enhances understanding (Oliver et al., 2021). According to Sulisworo et al. (2024), VR-based respiratory modules helped students reduce misconceptions and improved memory retention.

In one study, students who used VR to study the human respiratory system demonstrated higher Post Test scores and fewer errors in explaining oxygen diffusion compared to peers taught via traditional methods (Topalska, 2024). Another empirical study by Mu et al. (2024) emphasized the spatial and sequential clarity provided by VR, which supported deeper learning of physiological systems.

This enhanced visual experience aligns with dual coding theory, which states that learning is more effective when verbal and visual information are processed simultaneously (Paivio, 1990). Therefore, VR not only improves visualization but also supports deeper, multimodal understanding of biological systems.

2.8 Traditional Versus Technology-Based Instruction in Science Education

Traditional science instruction in middle schools has long relied on textbooks, teacher lectures, chalkboard diagrams and occasional laboratory demonstrations. While these methods provide foundational knowledge, they often lack interactivity and fail to address diverse learning needs (NRC, 2000; Bybee, 2013). Text-heavy resources may not adequately engage visual and kinesthetic learners and limited lab time constrains hands-on exploration of abstract concepts like cellular respiration or organ system interactions (Abrahams & Millar, 2008).

Technology-based instruction, particularly through Virtual Reality (VR), has emerged as a powerful alternative, offering immersive, student-centered learning environments that support visual-spatial reasoning, engagement and personalized pacing (Bower et al., 2020; Radianti et al., 2020). In comparative studies, students taught with VR tools outperformed peers taught through traditional means in knowledge acquisition, motivation and long-term retention (Portuguez-Castro & Garduño, 2024).

VR enables dynamic simulations of scientific phenomena that are otherwise invisible or abstract—such as alveolar gas exchange or molecular bonding—offering a level of experiential learning that traditional methods cannot match (Wu et al., 2021). Furthermore, students often report higher satisfaction and interest when learning through interactive technologies (Permana et al., 2019) supporting the shift toward technology-enhanced pedagogy.

Despite these advantages, challenges persist, including infrastructure requirements, training gaps and curriculum alignment (Samala, 2025). Nonetheless, the pedagogical benefits of VR strongly suggest its complementary role in enhancing, rather than replacing, traditional science instruction.

2.9 Real-World Application of Knowledge Facilitated by VR

One of the most significant benefits of Virtual Reality (VR) in science education is its ability to connect classroom knowledge with real-world applications. Traditional instruction often isolates content from context, making it difficult for middle school students to understand the relevance of scientific concepts in daily life (Bransford et al., 2000; Kolodner et al., 2003). VR addresses this disconnect by providing immersive environments where learners can simulate real-life scenarios, perform scientific tasks and apply their understanding in meaningful ways (Fowler, 2015).

For example, a VR module may allow students to diagnose respiratory diseases, conduct a virtual experiment on air pollution's effect on lung function, or simulate a field investigation of a public health issue—experiences that mirror authentic scientific practice (Wormser et al. (2025).) These scenarios promote situated learning, where knowledge is constructed in contexts that closely resemble its practical use (Brown et al., 1989).

Study by Sasso et al. (2024) shows that students who engage with such realistic VR tasks demonstrate improved problem-solving, better conceptual transfer and a clearer understanding of science's role in society. Furthermore, VR helps foster career awareness by exposing students to science-related professions and tasks in a risk-free environment (Radianti et al., 2020).

Thus, VR not only enhances conceptual knowledge but also empowers students to see science as dynamic, relevant and applicable beyond the classroom.

2.10 Comparative Studies on Conventional and VR-Based Science Teaching

Comparative studies between traditional and Virtual Reality (VR)-based science instruction consistently reveal significant differences in learning outcomes, student engagement and cognitive development. While conventional teaching methods—such as textbook reading, lectures and static diagrams—remain valuable, they often lack the sensory engagement and interactivity that VR provides (Bybee, 2013; Abrahams & Millar, 2008). As a result, VR has emerged as a compelling alternative, particularly for complex scientific subjects like human biology.

Numerous experimental and quasi-experimental studies have shown that VR instruction leads to higher academic achievement compared to traditional approaches. For instance, Soliman et al. (2022) found that students using VR for biological dissections retained more content and demonstrated greater procedural understanding than those using physical models or textbook exercises. Similarly, Wu et al. (2021), in a meta-analysis of 38 studies, confirmed that VR-enhanced science learning had medium-to-large positive effects on students' cognitive gains.

Furthermore, VR fosters deeper conceptual clarity by enabling learners to visualize dynamic processes—such as respiratory gas exchange or cellular respiration—in 3D, real-time environments (Andayani et al. 2019). Comparative studies also show higher levels of motivation, participation and self-efficacy in VR classrooms (Parong & Mayer, 2018; Sulisworo et al., 2024).

However, challenges such as cost, accessibility and teacher training must be considered (Radianti et al., 2020). Despite this, empirical evidence overwhelmingly supports VR as a

transformative tool that complements and, in many contexts, surpasses conventional methods in science education.

2.11 Empirical Research on VR in Indian and Global Educational Contexts

Empirical research on Virtual Reality (VR) in education has grown rapidly across both global and Indian contexts, revealing promising applications in science instruction at the middle school level. While early studies emerged from technologically advanced countries such as the United States, South Korea and Finland (Radianti et al., 2020), recent years have seen an increasing number of Indian researchers exploring the pedagogical potential of VR, particularly in biology education.

In global studies, VR has been shown to enhance conceptual clarity, engagement and knowledge retention across diverse learner populations (Sadanala, 2025). For example, in Denmark, Makransky et al. (2020) found significant learning gains when students used immersive VR simulations for biology lessons. In the United States, Parong and Mayer (2018) demonstrated improved science learning and reduced cognitive overload through immersive learning platforms.

In India, researcher Sulisworo et al. (2024) has applied VR tools to teach topics like the respiratory and circulatory systems. Although infrastructure and accessibility pose challenges, findings show strong improvements in student performance, satisfaction and participation, especially in rural or underserved schools. Jain et al. (2023) emphasized VR's role in closing the urban-rural education gap and called for broader implementation through public-private partnerships.

While the global literature supports VR as a transformative tool in science education, Indian empirical research indicates its immense untapped potential, provided logistical and infrastructural barriers are addressed through policy, funding and teacher training.

VR in Middle School Science Education

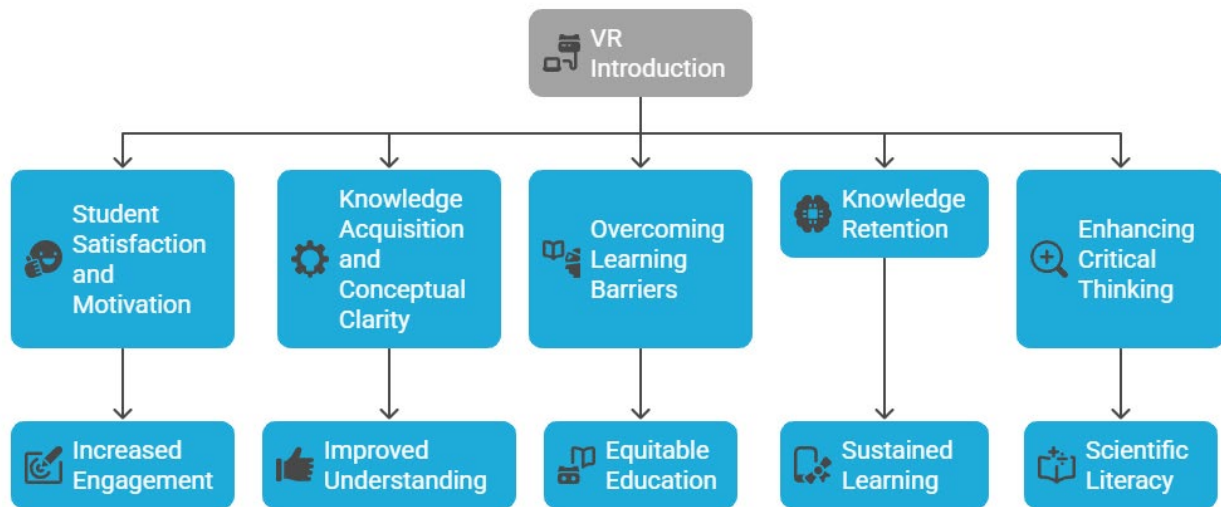


Fig. 2.4 Learning Outcomes and Student-Centered Benefits

2.12 Impact of VR on Student Engagement in Science Classrooms

Student engagement is a critical factor in effective science education, influencing motivation, attention, persistence and overall academic performance (Fredricks et al., 2004). Traditional teaching methods often struggle to maintain engagement, particularly when dealing with abstract or complex topics like the respiratory or circulatory systems (Liu et al., 2009). Virtual Reality (VR), by contrast, offers an immersive, interactive experience that captures students' attention through sensory stimulation and active participation (Evanjeli et al, 2024).

Numerous studies have confirmed that VR significantly enhances both behavioral and emotional engagement in middle school science classrooms. For example, Radianti et al. (2020) found that students using VR-based simulations spent more time on tasks and were more likely to express curiosity and enthusiasm for scientific topics. The immersive nature of VR enables students to take on the role of active explorers rather than passive recipients of information (Jensen & Konradsen, 2018).

Sasso et al. (2024) demonstrated that narrative-driven VR experiences like *OcuLeO* significantly increased students' intrinsic motivation and reduced off-task behavior. Similarly, Abrams et al. (2024) showed that even students with learning disabilities remained more

focused and engaged during VR-based vocabulary lessons. These findings suggest that VR doesn't just engage-it can democratize access to meaningful science education.

By transforming science classrooms into interactive learning environments, VR helps bridge the gap between interest and understanding, especially for learners who are otherwise disengaged or underperforming.

2.13 Student Satisfaction and Motivation in VR-Based Learning

Student satisfaction and motivation are essential for sustaining engagement and improving learning outcomes, particularly in science education where abstract content can feel disconnected from students' lives (Pintrich & De Groot, 1990). Virtual Reality (VR) offers high levels of interactivity, personalization and impressiveness, all of which contribute to greater learner satisfaction (Evanjeli et al, 2024). Middle school students, in particular, respond positively to technology-enhanced learning environments that offer autonomy and a sense of presence (Ryan & Deci, 2000).

Studies show that VR increases both intrinsic and extrinsic motivation. For example, Schloss et al. (2020) found that students reported higher enjoyment and perceived relevance during VR-based biology lessons than in traditional lectures. Sasso et al. (2024) demonstrated that a narrative-driven VR environment (OcuLeO) improved student attitudes toward science learning and fostered self-directed exploration. Similarly, Battipede (2024) reported a marked increase in students' enthusiasm and satisfaction when using VR.

The motivational impact of VR can be explained through Self-Determination Theory, which emphasizes the roles of autonomy, competence and relatedness in fostering motivation (Deci & Ryan, 1985). VR supports these needs by enabling students to explore at their own pace, manipulate 3D models and collaborate in shared virtual spaces.

Overall, student satisfaction in VR-based learning reflects not just novelty but a deeper emotional and cognitive engagement with science content.

2.14 Knowledge Acquisition and Conceptual Clarity through VR

One of the primary goals of science education is not only to transmit facts but to promote deep understanding of complex concepts. Virtual Reality (VR) has been found to significantly

enhance knowledge acquisition and conceptual clarity by enabling students to interact with scientific phenomena in ways that are not possible through traditional means (Parong & Mayer, 2018). The immersive nature of VR facilitates embodied cognition, allowing learners to internalize abstract ideas through active exploration and multisensory engagement (Lindgren et al., 2016).

Research consistently shows that students using VR outperform peers taught through conventional instruction in understanding dynamic systems such as respiration, photosynthesis and organ function (Wu et al., 2021). For example, Sulisworo et al. (2024) demonstrated that students using VR in biology classrooms scored significantly higher in knowledge retention tests and showed fewer misconceptions. Similarly, Topalska (2024) observed that students could articulate biological processes with greater precision after VR-based instruction.

The visual and interactive components of VR support dual coding and cognitive load theories, reducing extraneous processing while enhancing meaningful learning (Paivio, 1990; Sweller, 1988). Moreover, VR provides immediate feedback and allows repeated exposure, which reinforces accurate mental models and supports long-term memory.

Therefore, VR is not just a tool for engagement-it is a powerful cognitive aid that fosters deeper conceptual understanding in middle school science education.

2.15 Effectiveness of VR in Overcoming Science Learning Barriers

Science learning at the middle school level often presents multiple barriers, including conceptual difficulty, abstract content, lack of motivation, diverse learning needs and limited access to practical experimentation (Osborne & Dillon, 2008). These challenges are particularly evident in subjects such as human biology, where internal processes and microscopic structures are difficult to visualize or experience directly. Virtual Reality (VR) has emerged as an effective pedagogical tool to address and overcome these barriers (Radianti et al., 2020).

VR's immersive and interactive nature supports experiential learning and reduces cognitive overload by integrating visual, auditory and kinesthetic elements (Wen et al, 2024). For students with learning disabilities, VR has proven especially effective in simplifying complex

topics through step-by-step simulations and multimodal representations (Abrams et al., 2024). This inclusive helps bridge performance gaps and supports differentiated instruction.

Studies show that VR can eliminate the limitations of traditional labs, such as resource scarcity, safety concerns and time constraints. For example, students can perform a virtual dissection of the respiratory system without ethical or logistical challenges (Soliman et al., 2022). Moreover, students in rural or under-resourced schools' benefit from VR's ability to simulate advanced scientific equipment and experiments otherwise unavailable to them (Topalska, 2024).

By enabling personalized pacing, reducing reliance on rote learning and supporting inquiry-based exploration, VR not only mitigates traditional learning barriers but also fosters a more equitable science education landscape.

2.16 VR and Knowledge Retention among Middle School Students

Knowledge retention is a key indicator of instructional effectiveness, particularly in science education, where students often struggle to retain and apply abstract concepts over time (Anderson, 2010). Traditional teaching methods, while effective in initial content delivery, often result in surface-level learning and rapid forgetting (Ebbinghaus, 1885; Bransford et al., 2000). Virtual Reality (VR) offers an immersive, emotionally engaging and multisensory learning environment that significantly enhances long-term knowledge retention (Makransky & Peterson, 2021; Parong & Mayer, 2018).

VR's interactivity encourages active learning, which has been shown to result in better retention than passive instruction (Chi & Wylie, 2014). For instance, when middle school students navigate a VR model of the respiratory system, they are more likely to remember anatomical structures and physiological functions due to the dual coding of visual and verbal inputs (Paivio, 1990). This integration leads to stronger memory traces and greater retrieval accuracy (Lindgren et al., 2016).

Empirical studies support this claim. Sulisworo et al. (2024) found that students using VR biology modules scored higher on delayed Post Tests than their peers in traditional settings. Similarly, Huang, (2019) reported improved retention of key terms and scientific explanations after VR-based instruction. These findings are particularly relevant for middle school learners, whose cognitive abilities are still developing and benefit from concrete, experiential learning.

In sum, VR not only improves immediate understanding but also strengthens memory retention, a crucial outcome for sustained scientific literacy.

2.17 Enhancing Critical Thinking and Cognitive Skills through VR

Critical thinking and cognitive skills are essential for developing scientific reasoning, problem-solving and inquiry-based learning-especially at the middle school level where students begin to apply logic and evidence-based analysis (Halpern, 1998; Kuhn, 1999). Virtual Reality (VR) environments can significantly enhance these higher-order thinking skills by simulating real-world scenarios, fostering decision-making and enabling exploratory learning (Lindgren et al., 2016; Fowler, 2015).

VR enables students to actively engage with science concepts through manipulation, experimentation and problem-solving. For instance, a VR simulation of the respiratory system might challenge students to diagnose a breathing disorder based on symptoms and anatomical insights, promoting critical thinking and application of knowledge (Zackoff et al., 2024). This aligns with Bloom's revised taxonomy, supporting cognitive processes such as analysis, synthesis and evaluation (Anderson & Krathwohl, 2001).

Research by Essoe, (2021) confirms that VR-based learning leads to increased levels of cognitive engagement and improved scientific reasoning. Moreover, the immersive context of VR promotes metacognitive reflection, as learners assess their decisions and refine strategies in real-time (Parong & Mayer, 2020).

By transitioning from rote memorization to analytical learning, VR nurtures a deeper understanding of content while developing 21st-century skills such as critical thinking, adaptability and reasoning—skills essential for future scientific literacy and lifelong learning.

2.18 Social and Collaborative Learning Through VR

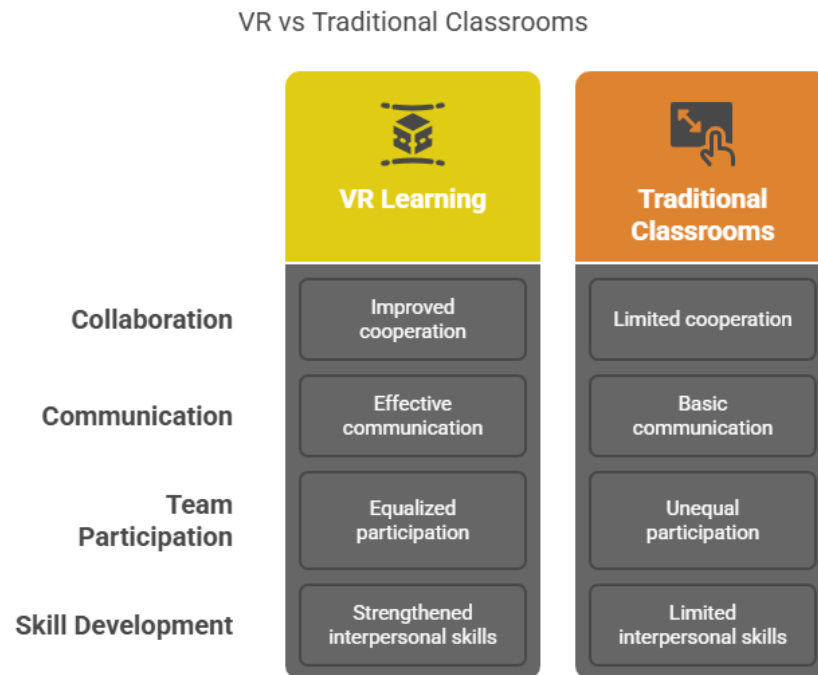


Fig. 2.5 VR vs Traditional Classrooms

Collaboration is a vital component of effective science education, fostering communication, problem-solving and shared meaning-making among students (Johnson & Johnson, 1999). In recent years, Virtual Reality (VR) has evolved from an individual learning tool to a social platform capable of supporting collaborative and peer-based learning in science classrooms (Dalgarno & Lee, 2010; Slater & Wilbur, 1997).

Multi-user VR environments allow students to interact, share resources, co-explore virtual simulations and discuss scientific phenomena in real time (Pan et al., 2006). For example, learners can work in teams, collaboratively troubleshoot problems and communicate observations, thereby mimicking authentic scientific collaboration (Hur et al., 2025).

Research by Bower et al. (2020) confirms that VR can enhance cooperative learning by providing shared immersive spaces where students take on complementary roles and learn from peer interaction. Such collaboration supports Vygotsky's social constructivist theory, emphasizing the importance of social interaction in cognitive development (Vygotsky, 1978).

Furthermore, VR fosters equal participation by allowing introverted or hesitant students to express themselves in low-risk, anonymous environments, reducing social anxiety and fostering inclusive discussions (Jensen & Konradsen, 2018).

Ultimately, VR extends the possibilities of traditional group work by offering shared, interactive experiences that support peer-to-peer teaching, collaborative problem-solving and community-building—critical elements for deep and meaningful science learning.

2.19 Development of Teamwork and Communication Skills in Virtual Spaces

The ability to collaborate and communicate effectively is increasingly emphasized in 21st-century education and is especially critical in scientific inquiry, where teamwork drives discovery and innovation (Partnership for 21st Century Skills, 2019). Virtual Reality (VR) learning environments offer unique opportunities to cultivate these competencies by enabling students to interact in shared, task-driven virtual spaces (Dalgarno & Lee, 2010; Slater & Wilbur, 1997).

Unlike traditional classrooms, VR platforms can simulate collaborative laboratories, emergency response simulations, or ecological field studies, where students assume different roles and must work together to achieve shared goals (Pan et al., 2006). These immersive simulations not only support subject learning but also strengthen interpersonal and leadership skills, as learners communicate findings, delegate tasks and reflect on group performance (Bower et al., 2020).

Research by Parong and Mayer (2020) found that students participating in team-based VR science tasks showed improved cooperation and more effective communication than in non-immersive settings. Similarly, Neher et al., (2024) highlight that VR can increase team communication and collaboration among students.

Furthermore, these environments align with collaborative learning theory and the idea that learning is socially constructed through interaction and dialogue (Vygotsky, 1978). VR facilitates this by immersing students in contexts that require real-time negotiation, reasoning and teamwork.

Thus, VR serves not only as a content delivery platform but also as a developmental tool for essential soft skills like teamwork, active listening and scientific communication.

2.20 Challenges and Future Prospects of VR in Indian Schools

VR in Indian Middle Schools: Challenges vs. Implications

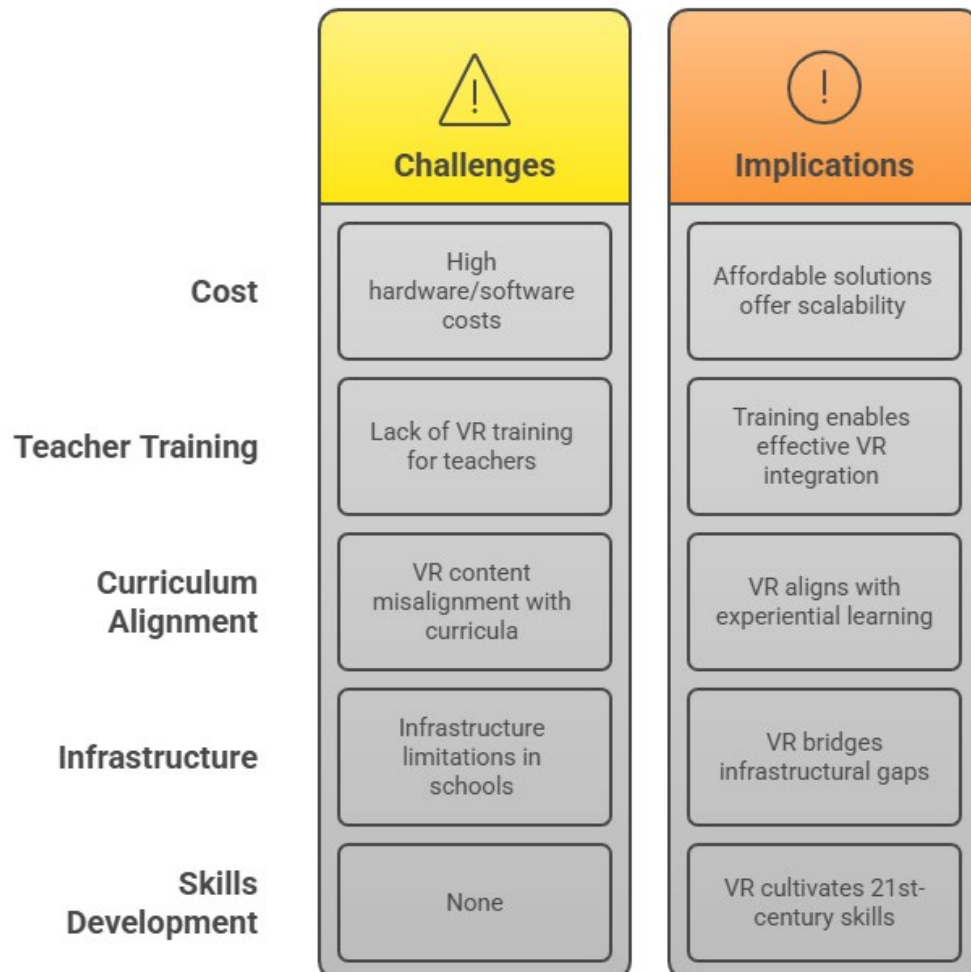


Fig. 2.6 Barriers to VR Integration in Middle School Classrooms

Despite its significant potential, the integration of Virtual Reality (VR) into middle school science classrooms is not without challenges. Numerous empirical and policy studies have identified barriers that hinder the widespread adoption of VR in educational settings, especially in developing countries like India (Radianti et al., 2020; Jain et al., 2023). These barriers include infrastructure limitations, cost constraints, lack of teacher training, curriculum misalignment and technological resistance.

High costs of VR hardware and software are a primary obstacle, particularly in public schools with limited funding (Bower et al., 2020). Devices such as VR headsets, powerful computers

and licensed educational content remain inaccessible to many institutions. In the Indian context, digital divides between urban and rural schools exacerbate inequality in access to immersive technologies (Jain et al., 2023).

Moreover, many teachers lack the technical skills or confidence to implement VR effectively (Pan et al., 2006). Teacher professional development programs rarely include training in emerging technologies, leaving educators underprepared to design or facilitate VR-based lessons (Freina & Ott, 2015).

Pedagogically, VR content may not always align with national curricula or assessment frameworks, leading to underutilization even when resources are available (Makransky & Mayer, 2022). Additionally, issues like motion sickness, privacy concerns and classroom management in multi-user VR environments have also been reported (Jensen & Konradsen, 2018).

Addressing these barriers will require coordinated efforts in teacher training, policy development, funding models and infrastructure enhancement to ensure equitable and sustainable VR integration in middle school science education.

2.21 Implications of VR for Future Pedagogical Innovation in Indian Schools

The integration of Virtual Reality (VR) into Indian middle school science classrooms holds transformative potential for pedagogical innovation. As India moves toward digital inclusion through initiatives like the National Education Policy (NEP) 2020, immersive technologies such as VR can play a pivotal role in modernizing science education, making it more interactive, accessible and relevant (Ministry of Education, 2020).

VR's ability to simulate real-world scientific phenomena aligns well with NEP 2020's emphasis on experiential, inquiry-based and competency-driven learning. It can shift instruction from rote memorization to exploration and application, making concepts like respiration tangible for young learners (Garderen et al. 2018). In resource-constrained environments, VR provides access to virtual labs and field experiences, thereby bridging infrastructural gaps, especially in rural areas (Jain et al., 2023).

Furthermore, the growing availability of affordable VR solutions and mobile-based headsets offers scalability in Indian classrooms (Topalska, 2024). With proper teacher training and

curriculum alignment, VR can foster differentiated learning, address diverse student needs and cultivate 21st-century skills such as critical thinking, collaboration and scientific reasoning (Fowler, 2015; Dede, 2009).

Policy reforms should therefore prioritize investment in VR content development aligned with national syllabi, inclusion in teacher education programs and collaborative research across schools, government and edtech startups. If strategically implemented, VR can significantly elevate science education quality and equity in Indian schools, transforming passive learners into active participants in the learning process.

2.22 Implications

The review underscores Virtual Reality (VR) as a transformative tool in middle school science education, especially for complex subjects like human biology. Its immersive nature fosters deeper conceptual understanding, improved retention and enhanced engagement. In the Indian context, VR can bridge educational disparities by providing equitable access to quality science instruction across urban and rural schools. Effective integration requires curriculum alignment, teacher training and infrastructural investment. Empirical studies affirm that VR supports critical thinking, collaboration and real-world application of knowledge. Addressing current implementation barriers is essential for scaling its benefits. As India embraces digital innovation, VR stands poised to redefine science pedagogy for future generations.

CHAPTER 3

METHODOLOGY

3.1 Overview

This research investigates the efficacy of Virtual Reality (VR) as a pedagogical tool in middle school science education, focusing on the human respiratory system. The methodology is structured around a mixed-methods approach involving both quantitative and qualitative data. The study integrates pre- and Post Test measures, surveys, interviews and focus group discussions. It applies experiential, cognitive and motivational learning theories. The findings are intended to inform curriculum design, teacher training and VR content development in Indian classrooms.

Introduction:

The sampling distribution across the three districts of Chennai—North, Central and South—shows a well-balanced selection from all the 3 educational zones, totaling 200 school samples for VR education and another 200 samples in the same schools for chalk & board conventional method. North Chennai contributes 72 samples each, drawn from zones like George Town, Perambur, Royapuram, Periamed, Purasaivalkam, , reflecting a consistent representation of urban and semi-urban educational environments, Central Chennai includes 71 samples each in both the groups, with zones such as Triplicane, Egmore, Ambattur, Koyambedu demonstrating a focus on densely populated, educationally active and South Chennai also accounts for 57 samples each , with representation in zones like Mylapore, Jafferkanpet, T.Nagar, Adyar likely reflecting the presence of growing residential areas and rich infrastructure localities. This distribution ensures that findings drawn from the study reflect a cross-section of Chennai's varied socioeconomic and educational settings. FGD comprising 10 students and 8 expert member interviews were also taken.

Table 3.1-ZONE WISE SCHOOLS

District	Zone	Sample Count - Chalk& Board	Sample Count - VR	Example School Name
North Chennai	Goerge Town	6	6	AGHS - George Town
	Perambur	48	48	GMS GKM Colony II
	Royapuram	6	6	GHSS Park Town
	Periyamed	6	6	AGHS Periyamed
	Purasaivalkam	6	6	DGHSS Purasaivalkam
Central Chennai	Triplicane	25	25	GMHSS Triplicane
	Egmore	10	10	GGMS Egmore
	Ambattur	20	20	KMHS Ambattur
	Koyambedu	16	16	GHSS Koyambedu
South Chennai	Mylapore	20	20	GHSS Mylapore
	Jafferkhanpet	25	25	GHS Jafferkhanpet
	T,Nagar	6	6	GGHS T.Nagar
	Adyar	6	6	AAGHSS Besant Nagar

The near-equal sampling across regions enhances the reliability and generalizability of the study, allowing for more comprehensive inferences regarding the impact of educational tools like Virtual Reality (VR) across different school environments in metropolitan Chennai.

3.2 Research Design

This study adopts a **quasi-experimental Pre Test–Post Test control group design** to investigate the pedagogical effectiveness of Virtual Reality (VR) in enhancing the understanding and retention of the respiratory system among middle school students. The aim

was to assess whether VR could enhance conceptual understanding, retention, engagement and collaborative learning compared to conventional chalk-and-board instruction. The intervention involved the development and application of a VR-based learning module titled “*Mrs. Jeevalatha Respiratory System Viscom and Animation*,” deployed through Oculus Quest 2 headsets with handlers. The VR lesson, lasting approximately 2 minutes and 20 seconds, provided immersive 3D experiences including visualizations of lungs, alveoli, air molecule travel, gas exchange and red blood cell function. The study was conducted over a 6-month period with baseline, immediate post-instruction and delayed retention assessments. Two groups of students were selected: one experimental group exposed to VR-based instruction and one control group taught through traditional methods. Both groups received the same content based on the Tamil Nadu State Board Grade 8 curriculum.

3.3 Hypothesis of the Study

Hypotheses and research designs were developed in accordance with the objectives, which were previously specified in Chapter 1.

Major Null Hypothesis with respect to Objectives:

H-I

Null Hypothesis H_0 : There is no significant difference between the chalk & board - control group and the VR - experimental group, in understanding the subject respiratory system

H-II

Null Hypothesis H_0 : There is no significant difference in the cognitive load and long-term retention level in remembering the subject respiratory system between the chalk & board & VR group

H-III

Null Hypothesis H_0 : There is no significant difference among the students with regard to student engagement, student satisfaction and learning interest, Learning

Resilience (overcoming learning difficulties) when subject is learnt through VR.

H-IV

Null Hypothesis H_0 : There is no significant difference among the students regarding social learning, leading to peer interaction and the development of teamwork and communication skills when learnt through VR.

Table 3.2 Hypothesis

S. No	Hypothesis	Null Hypothesis H_0
1	H1	There is no significant difference between the Chalk & Board and VR learning with respect to the understanding level of the students
2	H2	There is no significant difference in the total positive responses between male and female students with respect to the understanding level when taught through Chalk & Board
3	H3	There is no significant difference in the error percentage between the Pretest Chalk & board scores and Pre Test VR scores
4	H4	There is no significant difference between the understanding and retention level among students when taught through Chalk & Board
5	H5	There is no significant association between gender and Pre Test scores of chalk & Board, as tested by the Chi-square test.
6	H6	There is no significant difference between male and female students regarding experimental VR Pre Test scores pertaining to understanding level
7	H7	There is no significant difference between the chalk & board students and VR students with respect to the retention level
8	H8	There is no significant difference between the Pre Test and Post Test scores pertaining to understanding & retention level when learnt through VR
9	H9	There is no significant difference between the Post Test Scores of Chalk & Board and Post Test VR Scores

10	H10	There is no significant difference between male and female students with regard to the retention level of the students when taught through chalk & board -conventional method.
11	H11	There is no significant difference between male and female students with regard to retention level when respiratory system is taught through VR
12	H12	There is no significant difference between male and female students with regard to the Cognitive Load when subject respiratory system is learnt through VR
13	H13	There is no significant difference between male and female students with regard to Holistic Student Development
14	H14	There is no significant difference in students' Engagement across the 3 zones.
15	H15	There is no significant difference in Learning resilience across the 3 zones.
16	H16	There is no significant difference in student satisfaction across the 3 zones.
17	H17	There is no significant difference in interest to learn across the 3 zones.
18	H18	There is no significant correlation between Student Engagement & Learning Resilience
19	H19	There is no significant correlation between Student Engagement & Student Satisfaction
20	H20	There is no significant correlation between Student Engagement & Interest towards Learning
21	H21	There is no significant correlation between Overcoming Learning Difficulties and student satisfaction
22	H22	There is no significant correlation between Overcoming Learning Difficulties and interest towards learning
23	H23	There is no significant correlation between student satisfaction and interest towards learning

24	H24	Cognitive load does not significantly predict Post Test VR scores
25	H25	Student engagement does not significantly predict Post Test VR scores
26	H26	Overcoming Learning Difficulties does not significantly predict Post Test VR scores
27	H27	Student Satisfaction does not significantly predict Post Test VR scores
28	H28	Interest in coming to school does not significantly predict Post Test VR scores
29	H29	The hypothesized model does not have a good fit
30	H30	There is no significant difference between VR learning and peer interaction & communication
31	H31	There is no significant difference between male and female students with respect to Peer learning
32	H32	There is no significant difference in peers' communication among students across the three zones.

3.4 Sample and Setting

The sample pilot study was done which consisted of **60 students** from **two government middle schools** in Chennai. Each group comprises 30 students, selected through **purposive sampling** to ensure demographic diversity and infrastructure readiness. The study included students from Grades 7 to 8 with equal representation of genders. Parental and institutional consent was obtained before participation. Schools were selected based on School Principal and teacher's willingness to support VR integration.

The final data collection includes a total of **400 students** through random sampling from **Grade 8** across **multiple Chennai Corporation zones**. They were grouped into two equal sections: one receiving traditional chalk-and-board instruction and the other using the VR module. Schools were selected based on the principal approval and teacher support for VR integration and mainly the approval of conducting this VR study in all zones was taken from the District

Education Officer. The sample was balanced across gender (63% male, 37% female) and age (98% aged 13, 2% aged 14), ensuring homogeneity in learning levels.

3.5 Data Collection Tools

- **Pre Test:** Designed to assess students' understanding of the respiratory system, including multiple-choice questions and diagram-labeling. A structured 10-question conceptual test evaluated understanding of the respiratory system between the chalk & board and VR group
- **Post Test for Retention:** Conducted two months of post-intervention to assess long-term knowledge retention for both the groups
- **Survey:** A 25-item questionnaire gauging engagement, motivation, satisfaction and ease of learning with VR, cognitive load and peer communication.
- **Observation Checklist:** Observed class participation and attention span, peer interaction and communication skills
- **Focus Group Discussions:** Conducted with students to explore perceptions and challenges in using VR
- **Class Teacher & Subject Expert's Interviews:** Explored perceptions, usability, instructional value and peer learning

All tools were validated through expert reviews and pilot tested, achieving reliability scores (Cronbach's alpha > 0.80).

3.6 Data Analysis Plan

Quantitative data:

- Pre/Post Test: paired and independent **t-tests**
- Between-group comparisons: **ANOVA**
- Effect size: **Cohen's d**
- Survey: **Descriptive statistics** (mean, standard deviation, frequency)

Qualitative data:

- Interview & FDG Analysis – **Thematic Analysis** (Braun & Clarke, 2006)
- Themes included understanding, retention, engagement, satisfaction clarity and collaboration.

Triangulation was used for validating mixed-methods insights

3.7 Instructional Strategy

The VR content was developed in alignment with Kolb's Experiential Learning Cycle:

- **Concrete Experience:** Students explored a 3D simulation of the respiratory system
- **Reflective Observation:** Guided discussions encouraged reflection on their experiences
- **Active Experimentation:** Students manipulated the virtual lung model and engaged in hypothesis-based tasks

This constructivist approach ensured deep engagement and understanding, especially of abstract biological processes.

3.8 Pre Test and Post Test Procedure

The Pre Test assessed students' baseline understanding and ensured statistical equivalence between groups. Post Tests delayed test assessed student retention. All assessments were standardized and supervised by trained facilitators to ensure validity. Scores were analyzed using paired and independent t-tests, ANOVA and Cohen's d were used to measure effect size.

3.8.1 Pre Test

Pre Test was conducted to assess the understanding levels of Grade 8 students regarding the human respiratory system. This test was structured with multiple-choice questions 10 items which aligned with the Grade 8 science syllabus prescribed by Tamil Nadu Equal Education System.

The test was developed in consultation with subject experts and reviewed for curriculum alignment and content validity. A pilot run of the test was conducted among 10 students from a nearby school, which yielded a Cronbach's alpha reliability score of 0.82, confirming the internal consistency of the test items. The language of the test was simplified to ensure accessibility and reduce cognitive load.

In addition to subject content, the Pre Test also included a brief demographic questionnaire capturing age, gender, area, class and type of school.

The Pre Test was administered under standardized classroom conditions during regular school hours. Trained facilitators supervised the testing process to ensure uniformity. The results provided a quantitative baseline for comparing the learning gains in the post-intervention phase and ensured statistical equivalence between the experimental and control groups prior to VR exposure.

3.8.2 Post Test

Following the intervention, a Post Test identical to the Pre Test was administered to both experimental and control groups and the same set of questionnaires that was used during the Pre Test was conducted to the students two months after the initial Pre Test and administered. The Post Test served to evaluate the extent of knowledge retention following their respective instructional methods. Test conditions were standardized and proctored by facilitators uninvolved in instruction, ensuring objectivity and consistency.

Statistical analysis was performed using paired t-tests (within-group comparison of pre- and post-scores), independent t-tests (between-group comparison), Effect sizes were calculated using Cohen's d to determine the magnitude of VR's influence on student learning outcomes. The threshold of $d > 0.8$ was considered high impact.

Additionally, students submitted reflective responses about their learning experiences, focusing on VR usability, enjoyment and perceived improvement. These qualitative insights were coded thematically to triangulate quantitative findings. Together, the Post Test and reflections offered a comprehensive assessment of instructional effectiveness.

3.9 Survey and Quantitative Analysis

The post-intervention survey measured:

- Engagement with VR
- Learning motivation
- Usability and satisfaction
- Perceived learning effectiveness

Data were analyzed using descriptive statistics (mean, SD, frequency) and Chi-square tests for associations among variables. Exploratory Factor Analysis (EFA) was used to validate construct dimensions. Results were processed using SPSS.

A 5-point Likert-scale questionnaire consisting of 25 items was administered to all students in the experimental group post-intervention. The survey was designed to assess core domains: cognitive abilities, student engagement with VR content, emotional and motivational responses, learning effectiveness, usability and satisfaction with the VR platform and perceived reduction in learning barriers. The items were adapted and contextualized from validated instruments by Makransky et al. (2019) and Wu et al. (2021) and were reviewed by education technology experts to ensure cultural and curricular relevance.

The survey was distributed in paper format immediately after the final VR session, with classroom facilitators present to clarify instructions and ensure individual responses. Each student was given 15 minutes to complete the survey. Anonymity was ensured to reduce response bias and encourage honest feedback.

To ensure internal consistency, the instrument underwent a pilot test among 10 students from a nearby school not involved in the main study. Results from the pilot yielded a Cronbach's alpha of 0.88, indicating strong reliability.

Data were analyzed using descriptive statistics including mean, standard deviation and frequency counts for each item. Patterns in responses were compared with qualitative feedback obtained through interviews and focus groups. Open-ended items in the survey were thematically coded to extract recurring sentiments and insights related to VR's effectiveness in promoting engagement, understanding and motivation.

3.10 Qualitative Analysis

Interview transcripts were coded using Braun & Clarke's (2006) thematic analysis method. Themes included:

- Pedagogical impact
- Student behavior changes
- Implementation barriers
- VR integration challenges

- These insights were triangulated with quantitative findings to strengthen validity.

Interviews were held with:

- 2 Science Teachers
- 3 ICT coordinator
- 1 School Administrator
- 1 District Education Officer
- 1 Technology Expert

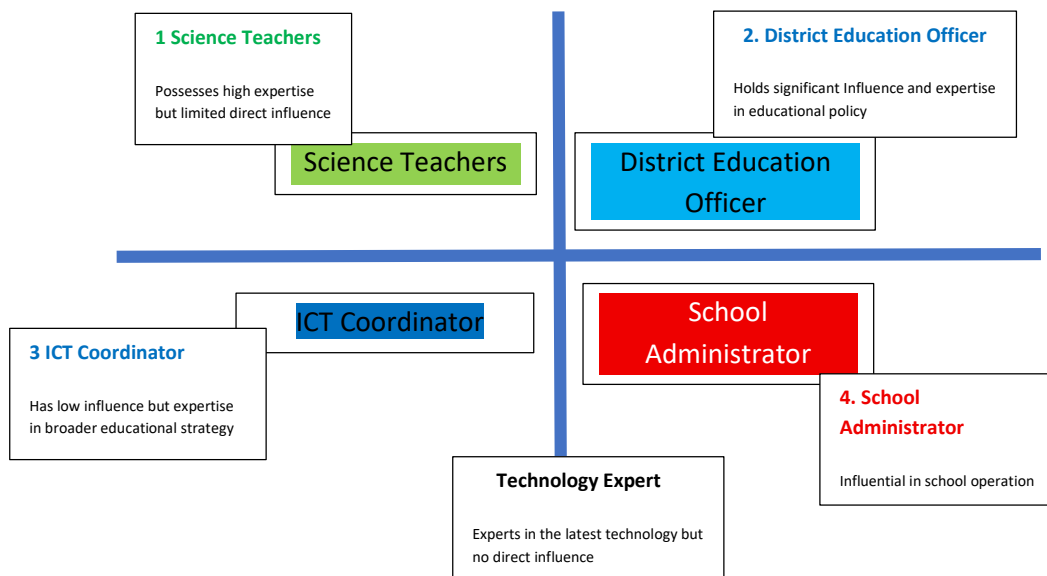


Fig. 3.1 Experts form base – to highest

Responses were transcribed and coded using thematic analysis (Braun & Clarke, 2006).

3.11 Pilot Study

To assess the feasibility and reliability of the research design, a pilot study was conducted involving 60 middle school students from a school not included in the main study sample. The objective was to test the VR instructional module, assessment instruments and data collection procedures prior to full-scale implementation. The pilot was instrumental in identifying and rectifying issues related to instructional flow, technical glitches and clarity of evaluation tools.

The pilot participants underwent the full sequence of the intervention, including the Pre Test, VR-based instruction on the respiratory system, Post Test and survey questionnaire.

Facilitators observed students for technical difficulties while using the VR headsets and recorded behavioral cues related to engagement and comprehension. Post-session debriefs allowed students to provide qualitative feedback on the VR experience, including interface usability, instructional narration and ease of navigation.

Key findings from the pilot indicated a high level of interest and immersion during the VR session but also highlighted the need for improvements in interface guidance, length of activities and content pacing. Accordingly, modifications were made to:

- Simplify technical instructions at the beginning of the session
- Reduce cognitive overload by segmenting content into smaller scenes
- Improve survey item clarity and flow
- Adjust timing of Post Test administration to minimize fatigue

The pilot study confirmed the feasibility, relevance and technical viability of using VR in a middle school setting and ensured the validity and reliability of the instruments before launching the main experimental phase.

3.12 Experimental Parameters

The experimental framework utilized a set of well-defined parameters to assess the effectiveness of VR-based pedagogy on middle school science learning. Each parameter was carefully selected to correspond with measurable educational outcomes and aligned with established learning theories.

- **Understanding level** was operationalized through standardized test scores, with correct responses to factual and conceptual questions indicating successful learning outcomes. This was grounded in **experiential learning theory** (Kolb, 1984), emphasizing knowledge construction through active engagement
- **Conceptual clarity** was assessed using diagram-based tasks, focusing on the learner's ability to understand system-level processes like gas exchange and diffusion mechanics. These tasks reflected **constructivist principles**, highlighting learning through contextual visualization
- **Knowledge retention** was evaluated via a delayed Post Test, administered 2 months after the intervention. It was used to determine long-term memory consolidation, drawing on cognitive information processing theory

- **Cognitive load** was measured through a self-reported 5-point scale administered with 10 questions, allowing students to rate mental effort. This aligned with Sweller's Cognitive Load Theory (1988), helping to identify whether VR reduced extraneous cognitive demands
- **Engagement and motivation** were analyzed through Likert-scale survey responses on interest, focus and enthusiasm. This parameter mapped onto Self-Determination Theory (Ryan & Deci, 2000), which emphasizes intrinsic motivation
- **Communication skills** were analyzed through students' participation in focus group discussions and responses to open-ended questions. Key indicators included clarity of explanation, vocabulary use and responsiveness to peer inputs

This multi-dimensional approach ensured a rich, theory-informed understanding of how VR affects diverse aspects of learning.

3.13 Experimental Analysis

This study adopts a **quasi-experimental Pre Test-Post Test control group design** to evaluate the effectiveness of virtual reality (VR) in teaching the respiratory system. Two groups were formed: the **experimental group**, which experienced immersive VR-based instruction and the **control group**, which received traditional instruction. The study is grounded in **experiential learning theory** (Kolb, 1984), **cognitive load theory** (Sweller, 1988), Social Constructivism Theory (Vygotsky, 1978) and Self-Determination Theory (Deci & Ryan, 1985)

**Quasi-Experimental Pre-Test-Post-test Design to
Assess the Effectiveness of VR-based Instruction (VR) in
Teaching Respiratory System**

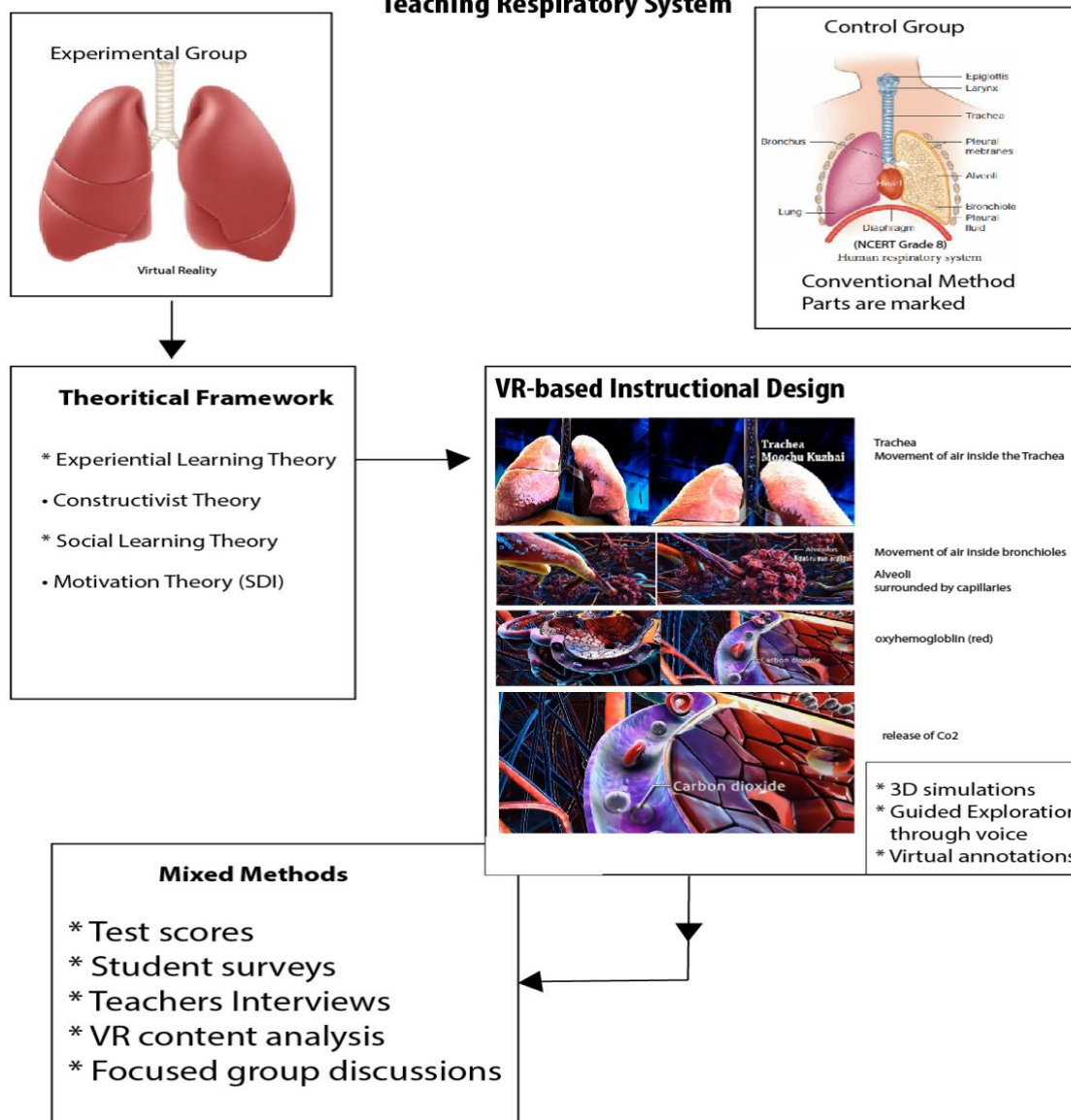


Fig. 3.2 – Effectiveness of VR based instruction

The instructional design for the experimental group included five 45-minute science periods over one week. VR content was aligned with the Tamil Nadu's Equal Education Grade 8 science curriculum, with emphasis on the structure and function of the respiratory system. Students used VR headsets to interact with 3D simulations of lungs, trachea, alveoli and gas exchange during breathing. Instructional scaffolding was provided through guided exploration tasks, virtual annotations and narration.

A mixed-methods design was used, incorporating test scores, student surveys, in-depth teacher interviews, VR content analysis and focused group discussions. The VR instruction aimed to provide multisensory learning to enhance conceptual clarity, engagement and motivation. This detailed design ensures reliable measurement of VR's pedagogical impact in a classroom context.

3.14 Research Method of Data Analysis of VR

The present study adopts a quantitative research approach to analyze the influence of Virtual Reality (VR) as a pedagogical tool on student understanding, retention, cognitive ability, student engagement, satisfaction, motivation to attend school, peer interaction and development of teamwork and communication skills.

Objective 1 aims to find out the understanding level of the student through a structured subject questionnaire and administered to students who have exclusively attended classes using VR to learn the respiratory system. The instrument consists of ten Objective type questions.

For **Objective 2**, which aims to investigate knowledge retention through the same subject questionnaire which will be tabulated and analyzed using frequency and percentage distribution. Each question targets specific concepts from the VR-based lesson (e.g., anatomical features of lungs, oxygen transport, color-coded visuals), allowing for a quantitative measure of how much content the students were able to recall even after two months. A high percentage of "Yes" responses will indicate effective knowledge retention attributed to the immersive and visual characteristics of VR and 10 questions for cognitive recall through ten dichotomous questions (Yes/No)

Objectives 3 assess student engagement, learning difficulty, satisfaction and interest in attending school through VR-based classes, responses are measured using a 5-point Likert scale: Strongly Agree, Agree, Neither Agree nor Disagree, Disagree and Strongly Disagree. Descriptive statistical techniques will be employed initially to compute the Mean, Standard Deviation and percentage of responses for each item under the domains of engagement, learning difficulties, satisfaction and school attendance interest.

Objective 4 aims to administer whether VR promotes Collaborative and Social Learning which leads to peer interaction and the development of teamwork and communication skills through

interviews from teachers, administrators, who were part of the observation team, Educationists and Director of School Education and FGD with students.

Further inferential statistical analysis will be conducted using **Chi-square tests** to identify significant associations between variables such as student engagement and satisfaction, VR classroom interest and attendance motivation. To determine the internal consistency and reliability of the Likert-scale sections, **Cronbach's Alpha** will be calculated. A reliability coefficient ($\alpha \geq 0.70$) will indicate acceptable internal consistency among the items. Additionally, exploratory factor analysis is employed to validate construct grouping, identifying underlying factors within the engagement, satisfaction and motivation questions. Cross-tabulations was used to compare trends among different demographic subgroups like gender and zone.

The cumulative results will help in understanding the behavioral, emotional and cognitive impacts of VR teaching. Patterns of high agreement with statements on learning ease and class interest will confirm VR's effectiveness. Data was entered and processed using statistical software to ensure precision. Graphs and charts (bar graphs, pie charts) were used to visually represent the findings for ease of interpretation. In summary, this structured data analysis plan combines both descriptive and inferential techniques to objectively assess the pedagogical impact of VR on students' academic experiences, allowing for evidence-based conclusions and recommendations.

3.15 Research Method of Data Analysis of Conventional Method

Conventional Chalk & Board Method analysis was done with the data collected in the Pretest and Post Test of conventional learning.

Traditional Teaching Method Evaluation

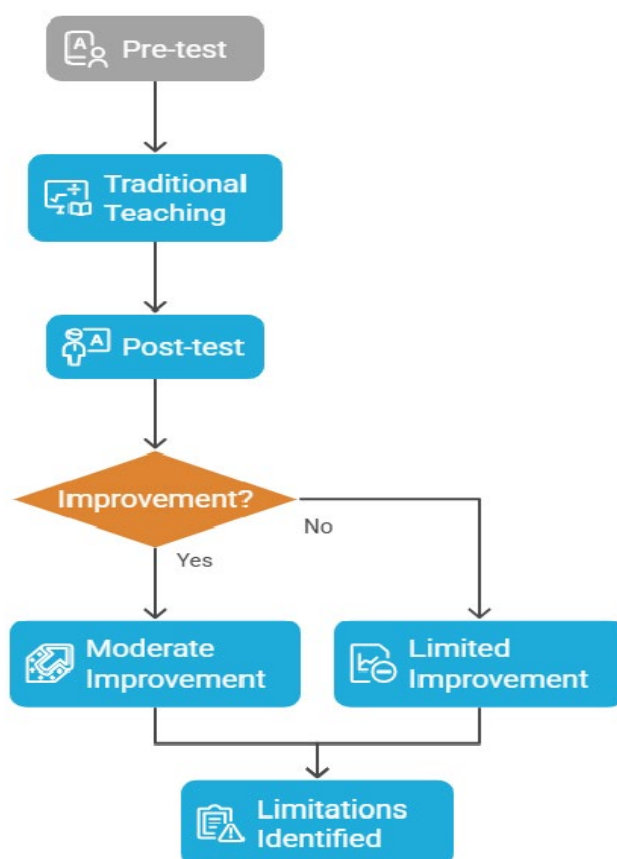


Fig. 3.3 Traditional Teaching Method Evaluation

The Pre Test conducted among students who were taught using the traditional chalk and board method revealed a limited foundational understanding of the respiratory system. The responses to the questionnaire highlighted conceptual confusion in areas such as the function of alveoli, the role of trachea and bronchus and the diffusion process involved in gas exchange. Specifically, a high percentage of students failed to correctly identify that hemoglobin binds with oxygen to form oxyhemoglobin and that carbon dioxide travels via diffusion. These misconceptions indicate that students had difficulties in retaining key terminology and physiological pathways from traditional instruction alone.

After the chalk and board-based teaching session, the same questionnaire was re-administered as a Post Test after 2 months to find the retention level. The Post Test results demonstrated a slight negative marking in student recollection level in almost all the subject questions. There were measurable improvements from the Pre Test to the Post Test, the conventional teaching

method showed limitations in ensuring deep conceptual clarity and long-term retention. Further comparison with VR results will help validate this finding.

3.16 Unit of Analysis

The primary unit of analysis was the individual student, with outcomes measured by test scores, survey responses and group participation. Secondary units included teacher's and administrator's perceptions and were analyzed qualitatively.

3.17 Ethical Considerations

Participation was voluntary and based on informed consent from both parents and institutions. Anonymity and confidentiality were assured. The study was approved by relevant school authorities and conducted in compliance with ethical research practices. Approval was obtained from school authorities and guardians before data collection.

3.18 Overall Flow of the Experimental Study Design (Simplified)

1. **Pre Test:** Assess understanding level of the respiratory system in both control and experimental groups.
2. **Intervention:**
 - **Control Group:** Traditional teaching methods (textbooks, lectures, 2D diagrams)
 - **Experimental Group:** VR-enhanced learning (immersive VR tours, interactive VR modules) combined with guided reflection and conceptualization
3. **Post Test:** Compare knowledge retention of the respiratory system between the two groups.
4. **Surveys:** Conducted surveys on cognitive load, students' engagement, motivation, perceived understanding and difficulties encountered.

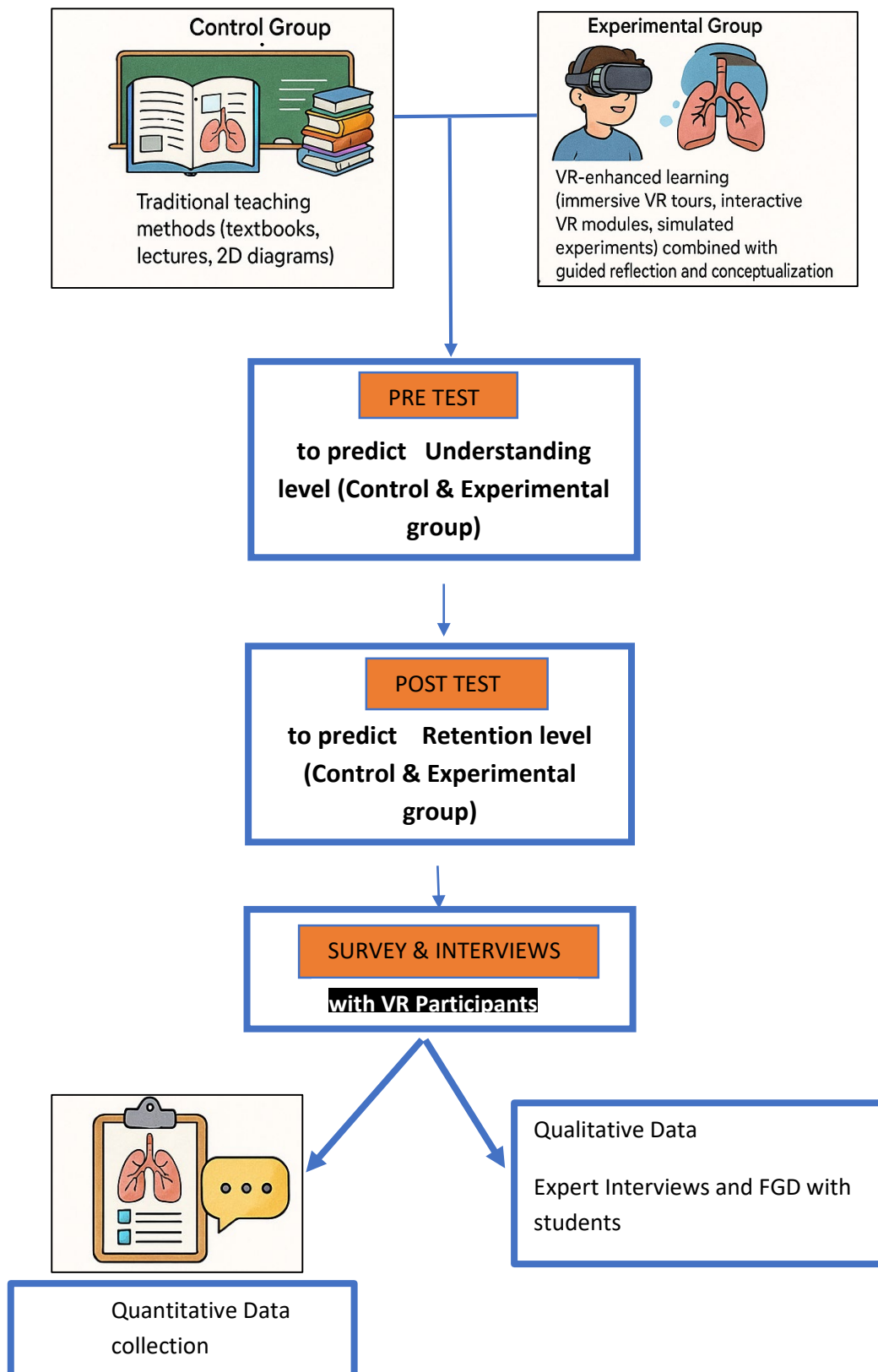


Fig. 3.4 Flow of the Experimental Study Design

This approach leverages Kolb's cycle by using VR to enrich the experiential aspects, thereby potentially improving knowledge acquisition and addressing common learning difficulties encountered by middle school students when studying complex biological systems like the respiratory system. Components are Attention, Retention, Reproduction, Motivation

- **Attention:** For learning to occur, the observer must pay attention to the model's behavior. Factors like the model's attractiveness, perceived similarity and the distinctiveness of the behavior influence attention
- **Retention:** The observer must be able to remember the observed behavior. This involves encoding the information into memory, often through mental images or verbal descriptions
- **Reproduction:** The observer must be able to physically and mentally reproduce the observed behavior. This requires having the necessary motor skills and the ability to convert symbolic representations into actions. Practice and feedback are crucial here
- **Motivation:** The observer must be motivated to perform the behavior. This motivation can stem from direct reinforcement (rewards), vicarious reinforcement (seeing the model rewarded), or self-reinforcement (internal satisfaction)
- Learning, practice behaviors and persist in their learning journey within the VR environment

By integrating VR into the learning process, the experimental study can provide a dynamic platform for students to learn about the respiratory system not just through direct instruction, but significantly through observing and imitating models, thereby harnessing the power of Bandura's Social Learning Theory.

3.19 Theories and its relationship with the Objectives

Table 3.3 Objectives, Theories and Methodology

S. No	Research Objective	Suitable Theoretical Framework(s)	Methodology
1	To examine the understanding levels of students taught through conventional methods versus VR	-Experiential Learning Theory (Kolb, 1984)	Pre Test - Experimental Design (Control vs. Experimental Group)- MCQs - Independent Samples T-test - ANOVA
2	To investigate the influence of virtual reality on students' knowledge retention and cognitive abilities.	-Cognitive Load Theory (Sweller, 1988)	- Delayed Post Test - MCQs - Independent Samples t-test - ANOVA
3	To examine the impact of virtual reality-based teaching methods on student engagement, satisfaction and interest toward learning and overcoming learning difficulties	-Self-Determination Theory (Deci & Ryan, 1985)	- Post Test Survey (Likert scale) - Observation Checklist - Focus Group Discussion (qualitative feedback)
4	To analyze whether students can have collaborative and social learning, leading to peer learning and the development of teamwork and communication skills	Social Constructivism Theory (Vygotsky, 1978)	- Peer Assessment Rubrics - Group VR Interaction Observation - Focus Group Discussions - Teachers Interviews - Thematic Analysis of reflections

3.19.1 Experiential Learning (EL)

Experiential Learning (EL) is an active, student-centered approach in which learners gain knowledge and skills through direct experiences, reflection and application (Kolb, 1984). Rooted in constructivist philosophy, EL assumes that learning occurs when individuals engage in a process that involves concrete experience, reflective observation, abstract conceptualization and active experimentation (Yardley et al., 2012). Unlike traditional rote learning, experiential approaches emphasize participation, problem-solving and the integration of theory with practice (Pasquale, 2013).

According to Kolb's **Experiential Learning Cycle**, the process begins with **concrete experiences**, where learners actively participate in meaningful tasks. This is followed by **reflective observation**, during which learners critically examine their experiences from multiple perspectives. **Abstract conceptualization** involves drawing conclusions and integrating theoretical frameworks. Finally, **active experimentation** applies these concepts to new situations, completing the cycle and deepening understanding (Boggu, 2020; Hiasat, 2018).

Experiential learning is widely recognized as effective in enhancing student engagement, motivation and knowledge retention (Bansode, 2021). The approach aligns well with immersive technologies such as **Virtual Reality (VR)**, which can create realistic simulations for learners to explore complex concepts in safe, controlled environments (Krouska et al., 2023). VR-based experiential learning supports active involvement, immediate feedback and repeated practice, leading to deeper cognitive processing compared to passive instruction (Jallad et al., 2024).

Research across disciplines confirms that EL improves the ability to transfer classroom knowledge to real-world contexts. In nursing education, for example, immersive VR experiences allowed students to integrate theoretical knowledge with practical skills more effectively than conventional lectures (Jallad et al., 2024). In science education, technology-enabled EL has been shown to support inquiry-based learning, problem-solving skills and long-term knowledge retention (Osorio & Aliazas, 2022).

A key strength of experiential learning lies in its adaptability. It can be implemented through fieldwork, laboratory experiments, role-play, case studies, simulations, service learning and cross-cultural exchanges (Ramirez, 2023; Wolfe 2006). These methods provide authentic contexts where learners can apply and refine their skills, thereby increasing self-efficacy and professional readiness (Deslauriers et al., 2016).

However, successful implementation requires intentional design. Experiences must be **meaningful**, directly linked to learning objectives and supported by structured reflection (Clark et al., 2010). Without guided reflection, learners may fail to connect practical experiences with theoretical insights, limiting the depth of learning (Yardley et al., 2012).

In contemporary education, experiential learning plays a critical role in bridging the gap between knowing and doing. As employers increasingly value problem-solving, adaptability and collaborative skills, EL offers a pedagogical framework to cultivate these competencies (Waheed & Waseem, 2023). Its integration with emerging technologies like VR further enhances its potential to create immersive, personalized and impactful educational experiences. Finally, experiential learning is more than a teaching method—it is a transformative learning philosophy that positions students as active participants in their education. By engaging learners in authentic, reflective and application-oriented activities, it fosters deeper understanding, stronger retention and the development of skills essential for lifelong learning in a rapidly evolving world.

This study aims to examine and compare the current understanding and knowledge levels of students when taught through conventional methods versus after instruction using **Virtual Reality (VR)** integrated within **Experiential Learning Theory (ELT)**. Conventional methods, including lectures and textbook-based instruction, provide structured delivery of theoretical content but often limit opportunities for active engagement and practical application (Pasquale, 2013). In contrast, VR-supported experiential learning offers immersive, interactive environments that enable students to actively participate, manipulate variables and reflect on outcomes, aligning with Kolb's learning cycle of concrete experience, reflective observation, abstract conceptualization and active experimentation (Kolb, 1984).

VR-Integrated Experiential Learning Study

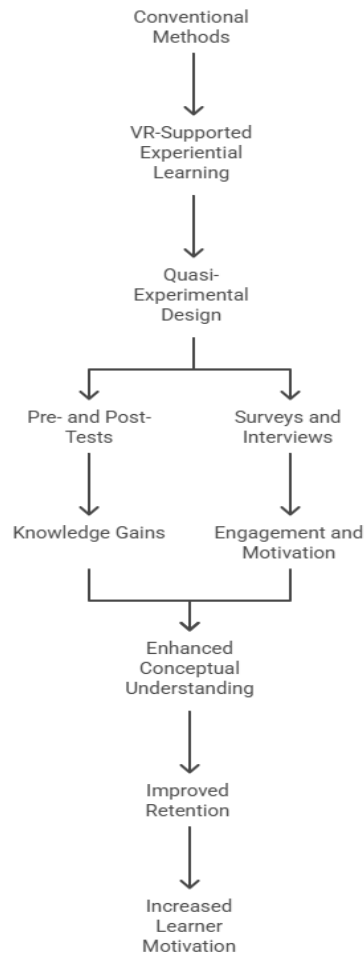


Fig. 3.5 VR – Integrated Experiential Learning Study

The study employs a quasi-experimental design with control (conventional) and experimental (VR-based) groups. Pre- and Post Tests will measure knowledge gains, while surveys and interviews will assess engagement, motivation and perceived learning benefits (Krouska et al., 2023). By integrating VR into EL, the research anticipates enhanced conceptual understanding, improved retention and increased learner motivation compared to traditional methods (Jallad et al., 2024; Bansode, 2021). Findings are expected to contribute to evidence-based educational practices, highlighting the pedagogical potential of VR as a transformative tool for experiential learning in middle school education.

3.19.2 Cognitive Load Theory (CLT)

Cognitive Load Theory (CLT), developed by Sweller (1988), explains how instructional design can optimize learning by considering the limitations of working memory and the role of long-term memory in schema acquisition (Sweller et al., 2011; Paas et al., 2003). CLT distinguishes **intrinsic load** (task complexity), **extraneous load** (unnecessary mental effort from poor design) and **germane load** (effort dedicated to learning processes) (Kalyuga, 2011; Van Merriënboer & Sweller, 2010).

Working memory has limited capacity (Baddeley, 1992), making it essential for educators to minimize extraneous load while supporting schema construction (Chandler & Sweller, 1991; Paas & van Merriënboer, 2020). Effective strategies include worked examples (Sweller & Cooper, 1985), modality effects (Mousavi et al., 1995) and segmenting principles (Mayer & Moreno, 2003).

In technology-enhanced learning, including **Virtual Reality (VR)**, CLT provides guidance to prevent cognitive overload while maintaining productive challenge (Liu et al., 2022; Mokmin et al., 2024). Proper VR design, incorporating scaffolding (Van Merriënboer & Kirschner, 2018) and signaling (de Koning et al., 2009), can lower extraneous demands and enhance engagement (Huang et al., 2018).

Empirical studies show that CLT-informed VR instruction can improve academic performance, motivation and knowledge retention in various fields including anatomy (Küçük et al., 2016), science (Lai et al., 2019) and engineering (Berssanette & de Francisco, 2021). CLT has also been adapted into collaborative contexts to leverage shared cognitive resources (Kirschner et al., 2018) and integrated with the **Cognitive Theory of Multimedia Learning** to address visual and auditory processing (Mayer, 2009).

When applied effectively, CLT ensures instructional efficiency by aligning cognitive demands with learner capacity, which is particularly crucial in immersive environments where sensory richness can otherwise overwhelm working memory (Schnotz & Kürschner, 2007; Hadie et al., 2021). By applying this to VR-based experiential learning, educators can balance cognitive demands, reduce distractions and promote deep processing. This ensures learners can focus mental resources on meaningful problem-solving and conceptual understanding, leading to improved academic performance and sustained retention of knowledge.

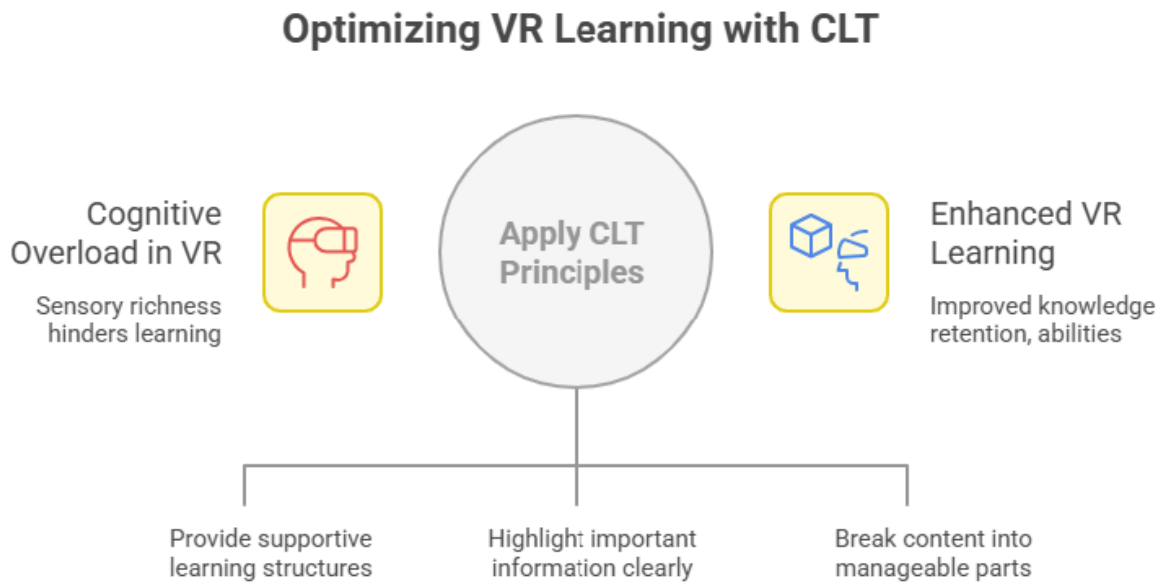


Fig. 3.6 Optimizing VR Learning with Cognitive Load Theory (CLT)

In the context of **Virtual Reality (VR)** learning, CLT is critical for preventing cognitive overload while maintaining optimal challenge levels. Immersive VR environments can enhance **knowledge retention** and **cognitive abilities** by creating realistic, interactive experiences that foster engagement (Liu et al., 2022; Mokmin et al., 2024). However, without careful instructional design—such as scaffolding, signaling and segmentation—VR’s sensory richness may increase extraneous load and hinder learning (Van Merriënboer & Sweller, 2010).

3.19.3 Self-Determination Theory (SDT)

Self-Determination Theory (SDT), developed by Deci and Ryan (1985, 2000), is a macro-theory of human motivation that explains how the fulfillment of three basic psychological needs—**autonomy**, **competence** and **relatedness**—drives optimal learning and well-being. Autonomy refers to experiencing choice and volition in actions, competence is the sense of mastery over tasks and relatedness involves feeling connected to others (Ryan & Deci, 2017; Chiu, 2022).

SDT distinguishes between **intrinsic motivation** (engaging in learning for inherent satisfaction) and **extrinsic motivation** (driven by external rewards), emphasizing that the quality of motivation matters more than its quantity (Howard et al., 2021). When learning environments support these needs, students exhibit higher engagement, persistence and

achievement (Sergis et al., 2018; Zhao et al., 2011; Butz & Stupnisky, 2017). Conversely, thwarting these needs can lead to disengagement and reduced learning outcomes (Flanigan et al., 2023).

In **technology-enhanced and virtual learning environments**, SDT provides a framework for designing experiences that maintain motivation. Studies have shown that VR-based education can enhance learner satisfaction and flow when autonomy-supportive elements, competence-building tasks and social interaction are integrated (Huang et al., 2019; Gim et al., 2022; Hwang & Chang, 2024). Gamification, mobile learning and AI-driven personalized learning tools have also been effective in meeting these needs (Luarn et al., 2023; Galindo-Domínguez et al., 2025).

SDT has been applied across contexts, including language learning (Dincer & Yesilyurt, 2017; Alamer & Al Khateeb, 2023), STEM education (Chiu et al., 2021), MOOCs (Alturki & Aldraiweesh, 2023) and blended learning (Chiu, 2021). In VR-based experiential learning, SDT complements **Cognitive Load Theory** by ensuring that motivation is sustained alongside cognitive efficiency (Rosli & Saleh, 2023; Yang et al., 2019).

Ultimately, SDT offers a robust theoretical lens for designing VR learning environments that not only deliver content effectively but also foster sustained intrinsic motivation, engagement and satisfaction.

VR-Based Learning and Self-Determination Theory

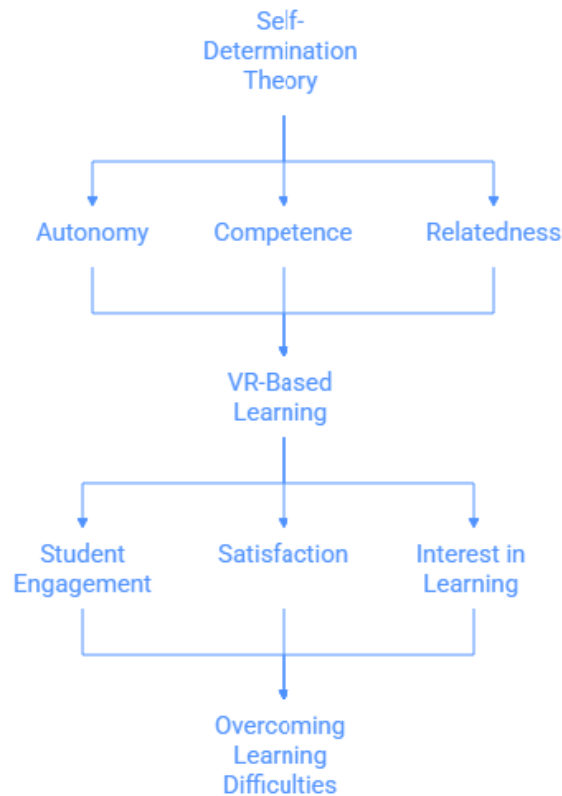


Fig. 3.7 VR Based Learning and Self Determination Theory

3.19.4 Social Constructivism Theory (SCT)

Social Constructivism Theory (SCT), rooted in the works of Vygotsky (1978), posits that knowledge is constructed through **social interaction**, cultural context and collaboration. Unlike individual cognitive constructivism (Piaget, 1972), SCT emphasizes the role of language, dialogue and shared problem-solving in learning (Woo & Reeves, 2007; Amineh & Asl, 2015). Central concepts include the **Zone of Proximal Development (ZPD)**—the gap between what a learner can achieve independently and with guidance—and **scaffolding**, the temporary support provided to facilitate skill mastery (Wood et al., 1976; Churcher et al., 2014).

In educational settings, SCT promotes **student-centered learning**, peer collaboration and real-world contextualization of knowledge (Azhari et al., 2020; Umar et al., 2023). Digital

technologies, including **Virtual Reality (VR)**, extend SCT principles by enabling authentic, immersive experiences where learners co-construct understanding (Onyesolu et al., 2013; Huang & Liaw, 2018). VR can facilitate teamwork, communication skills and cultural competence through simulated environments (Chau et al., 2013; Barak, 2017).

Studies show that when VR is integrated with SCT strategies, it enhances learner engagement, motivation and performance (Liu et al., 2010; Alismaiel et al., 2022). Collaborative VR tasks foster peer-to-peer learning and deepen conceptual understanding (Boland, 2009; Foko & Amory, 2008). Additionally, SCT-based VR approaches have been effective in language acquisition (Aravind & Bhuvaneswari, 2023), STEM learning (Barak, 2017) and professional training (Thomas et al., 2014).

In the context of **Virtual Reality (VR)**, SCT provides a framework for examining how immersive environments promote **collaborative and social learning**. VR can simulate authentic, interactive settings where students engage in joint problem-solving, share perspectives and build knowledge collectively (Huang & Liaw, 2018; Barak, 2017). Such environments encourage **peer interaction** by enabling learners to communicate, negotiate meaning and provide mutual feedback in real time (Boland, 2009; Onyesolu et al., 2013).

Research indicates that VR-based SCT activities foster the **development of teamwork and communication skills** by placing learners in cooperative roles that require coordination, decision-making and shared goal achievement (Foko & Amory, 2008; Alismaiel et al., 2022). Through these socially rich experiences, students not only enhance subject mastery but also cultivate interpersonal competencies essential for success in academic and professional contexts (Thomas et al., 2014; Zajda, 2023).

Thus, integrating VR with SCT principles transforms learning into a dynamic, socially engaging process that strengthens both cognitive and collaborative capacities.

By situating learning in **socially rich, interactive environments**, SCT ensures that knowledge acquisition is meaningful and transferable (Zajda, 2023).

Social Constructivism Theory in VR LEARNING

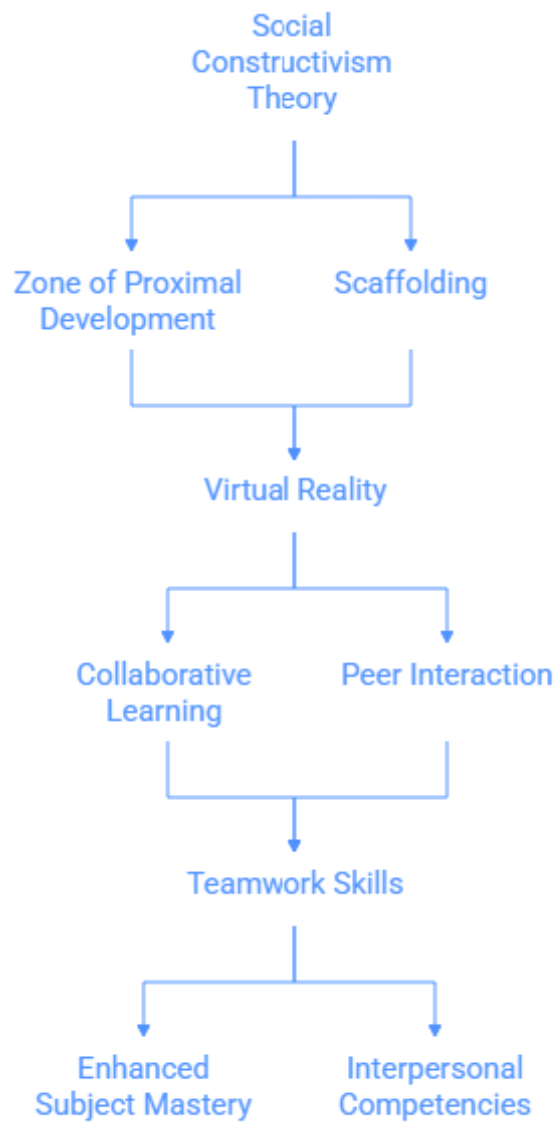


Fig. 3.8 Social Constructivism Theory in VR Learning

Social Constructivism Theory (SCT), proposed by Vygotsky (1978), emphasizes that learning is a socially mediated process where knowledge is co-constructed through interaction, collaboration and cultural context. Central to SCT are the **Zone of Proximal Development (ZPD)** and **scaffolding**, which highlight the importance of guided participation and peer support (Wood et al., 1976; Churcher et al., 2014).

3.20 About Development of the experimental VR Video and the method

An experimental Virtual Reality (VR) video was developed as a core component of this study to assess the effectiveness of immersive learning in teaching the human respiratory system to middle school students. The production timeline for the computer-generated (CG) content, including its conversion into a fully interactive VR format, spanned approximately one year. The final VR product, valued at approximately ₹4 lakhs, features a meticulously designed 3D model of the human lungs. Students were able to use VR headsets to virtually pick up the lung model, rotate it and closely examine its structure—an experience designed to bridge the gap between theoretical understanding and hands-on exploration.

The original duration of the VR simulation is 2 minutes and 20 seconds. This immersive learning tool was implemented in schools located in and around the three zones of Chennai. The survey began in January 2025, including the administration of Pre Tests and Post Tests and continued through April 2025. A follow-up retention test was conducted in June 2025, once students returned from vacation, to evaluate long-term knowledge retention.

Additional qualitative insights were gathered from expert educators, ICT coordinators and school principals. The relevant data files and professional opinions were analyzed.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Overview

This project describes the development and evaluation of an experimental Virtual Reality (VR) application designed to enhance middle school students' comprehension of the human respiratory system¹. Developed over approximately one year, the VR application features interactive 3D models of the lungs, allowing students to virtually manipulate and examine them². It integrates dynamic animations of physiological processes, such as air molecule pathways and gas exchange, and provides various interactive elements like virtual hands and teleportation³. The application serves as a core component of a research study aiming to assess the effectiveness of immersive learning in bridging the gap between theoretical understanding and practical exploration⁴. Its impact on student learning and retention is being rigorously evaluated through Pre Tests, Post Tests.

4.2 Experimental Virtual Reality Video for Respiratory System Education and Associated Research Methodology

This study presents the development and implementation of an experimental Virtual Reality (VR) video designed to evaluate the efficacy of immersive learning in middle school education, specifically focusing on the human respiratory system. The comprehensive production of the computer-generated (CG) content, including its transformation into a fully interactive VR format, spanned an approximate duration of one year. The resultant VR product, with an estimated valuation of ₹5 lakhs (approximately 6,000 USD), incorporates a meticulously rendered 3D model of the human lungs. This model allows students to engage in virtual manipulation, including picking up, rotating, and closely examining its anatomical intricacies. This interactive design aims to bridge the conventional gap between abstract theoretical knowledge and concrete, hands-on exploration, thereby enhancing student comprehension and engagement.

The VR simulation itself has an original runtime of 2 minutes and 20 seconds, optimized for focused and effective learning sessions. This innovative educational tool was deployed in schools situated within and around the from various corporation Zones of Chennai, India,

forming the geographical scope of the study's intervention. The data collection phase commenced in January 2025 with the administration of Pre Tests to establish baseline knowledge to measure immediate learning gains. This initial survey period concluded in April 2025. To ascertain the long-term retention of acquired knowledge, a follow-up retention test was meticulously conducted in June 2025, strategically timed after students' return from academic vacation to minimize external influencing factors.

Beyond quantitative assessment, the research methodology incorporated the gathering of qualitative insights from key stakeholders in the educational ecosystem. Expert educators, Information and Communication Technology (ICT) coordinators, and school principals provided valuable professional opinions and perspectives on the VR application's effectiveness, usability, and integration into existing curricula. These relevant data files, encompassing both quantitative test results and qualitative feedback, will be systematically submitted for rigorous analysis to draw comprehensive conclusions regarding the impact of VR-based learning.

The accompanying experimental video provides a detailed visual exploration of the developed VR application, offering insights into its immersive learning experience. The footage commences by showcasing the familiar interface of a VR headset's home screen, displaying standard functionalities such as "Cast," "Take Photo," and "Recording," which illustrate the initial user setup. The user's navigation through the VR environment is then highlighted, specifically demonstrating the selection and launch of "MyProject." The subsequent appearance of the "Unreal Engine" logo serves to confirm the underlying development platform, underscoring the advanced graphical capabilities and realism integrated into the application.

Upon successful entry into the "MyProject" application, the user is seamlessly transported into a virtual classroom environment, characterized by a realistic wooden floor texture. Within this simulated space, two virtual hands emerge, serving as the user's primary means of interaction and manipulation. An overlaid text prominently introduces the educational module as "Mrs. Jeevalatha Respiratory System Viscom and Animation," clearly delineating the application's pedagogical focus.

The core interactive experience centers around a large, orange circular platform featuring two distinct interactive prompts: a "QUIT button" and "Press the Button to open next level."

The user's virtual hand actively engages with the latter, initiating the transition to the next educational segment. This action reveals a prominent virtual screen displaying comprehensive anatomical diagrams of the human respiratory system, providing foundational visual information for learning.

Further into the demonstration, the user interacts to activate a dedicated video display. This video presents a highly detailed and dynamic animation of the respiratory system, offering a vivid visual journey through its intricate complexities. Following the animated presentation, the user is afforded the opportunity to directly manipulate a 3D model of the lungs and trachea, fostering a hands-on, interactive understanding of their structural relationships. The video further showcases an in-depth 3D animation of the human respiratory system, beginning with an overview of the lungs and ribcage, then progressively zooming to illustrate the intricate pathways of air. Viewers are guided from the nostrils and pharynx, through the trachea and bronchi, and finally into the bronchioles and alveoli. The animation vividly elucidates the gas exchange process, specifically highlighting oxygen absorption into red blood cells and the corresponding release of carbon dioxide within the capillaries surrounding the alveolar chambers, effectively visualizing the micro-level functionality of respiration.

The comprehensive demonstration culminates with the user navigating back to the main menu and gracefully exiting the application, bringing the recording to a close. This experimental video serves as compelling evidence of the potential of VR technology in crafting engaging, interactive, and highly effective educational content for complex biological subjects, promising to revolutionize traditional learning paradigms.

4.3 Descriptions of Visual Content from Virtual Reality Application Interface

The Virtual Reality (VR) application designed to teach the respiratory system offers a rich, immersive experience for learners by integrating visual, auditory, and kinesthetic learning elements. The sequence of images taken from the application demonstrates a thoughtful, structured learning journey—from initial access and interface navigation to interactive exploration of human anatomy and ultimately to exiting the session.

The journey begins with the **Entry Screen**, the home interface of the VR headset.

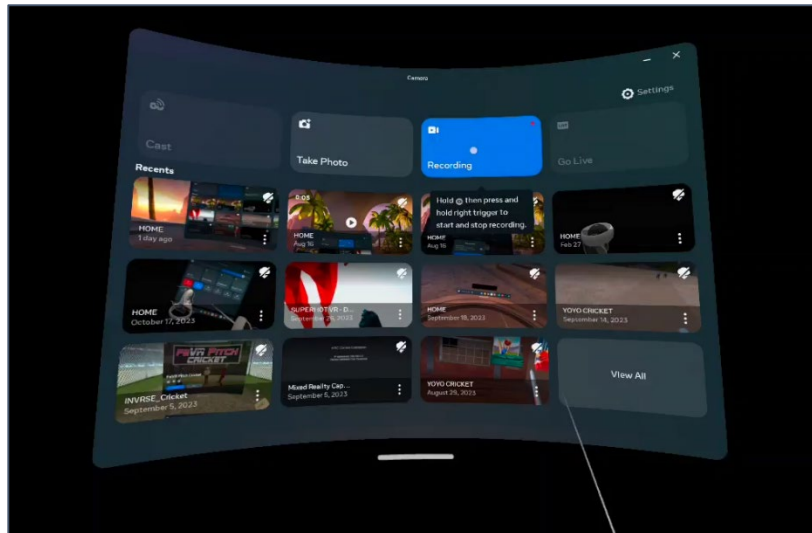


Fig. 4.1 Entry Screen of VR

This foundational screen provides access to system tools such as "Cast," "Take Photo," and "Recording," which ensure the user can manage their session efficiently. This preparatory interface is critical for system orientation and usability, especially for novice users. Following this, the **Hand Gloves Seen in VR World Screen** introduces virtual hand controllers, emphasizing direct interaction—a key strength of VR learning.

These gloved avatars empower users to grasp, lift, rotate, and reposition 3D objects, thus anchoring the experience in active engagement. Transitioning into the learning module is visually marked in the **Getting into the VR Project** image, where the project title “Mrs. Jeevalatha Respiratory System Viscom and Animation” is displayed.



Fig. 4.2 Hand Gloves -Virtual Hand controller for Interactivity -Prompt to Open or Quit

This marks the official start of the learning content. The user is soon prompted with the **Press to Play VR or Quit Button**, signaling a decision point—either to engage in or exit the educational experience. Such clear options support user autonomy and ease of navigation.

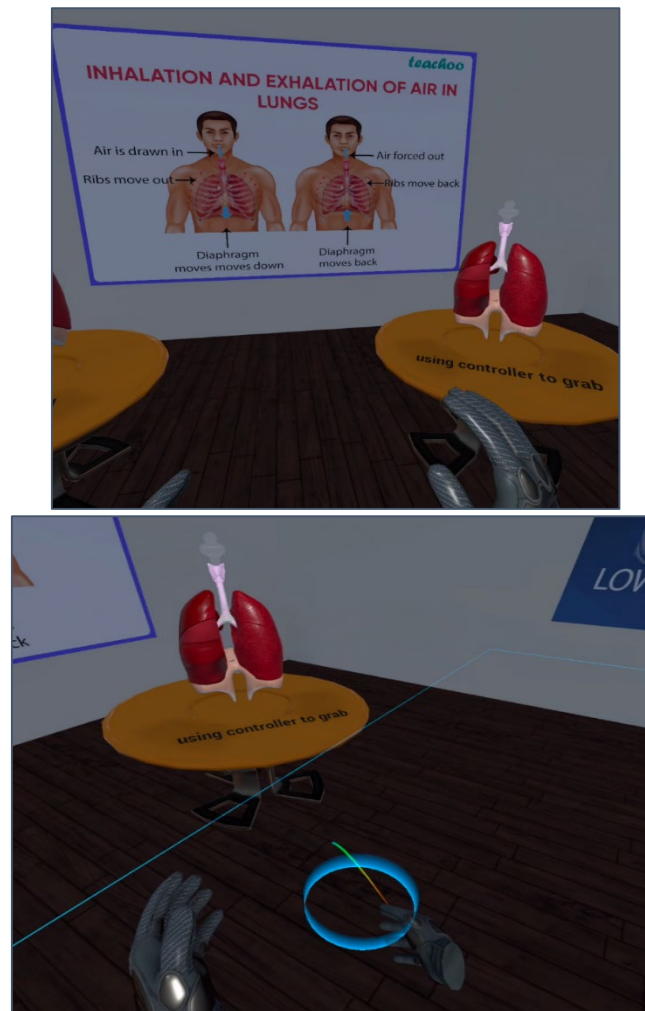


Fig. 4.3 Hand Controller to Grab - Teleport to bring the objects near

The above image introduces a blend of textual content and visuals explaining lung function during inhalation and exhalation. Learners are encouraged to interact with a 3D lung model, merging passive and active learning. Features like **Teleport to Bring it Near You** and **Moving Near to the Lungs** allows users to reposition and approach anatomical models, promoting detailed, personalized observation. This helps overcome limitations of traditional 2D diagrams. The following images, including **Holding the Lungs in Your Hand Using Gloves**, **Lifting the Lungs in Your Hands**, and **Rotate and See**, highlight tactile learning.

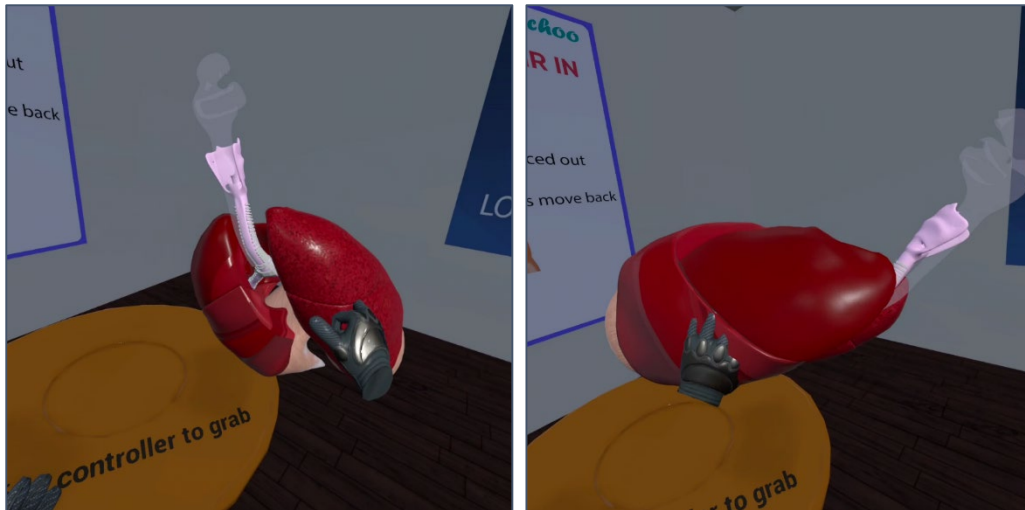


Fig. 4.4 Rotating the liver and seeing -using handler

Users can physically engage with the lung model—lifting and rotating it to view from multiple angles. These gestures mirror real-world object handling, making anatomy more intuitive and memorable. In **Rotating and Seeing**, the dynamic spinning of the lungs offers a complete spatial understanding. Subsequently, **keeping it Back** allows for controlled resetting of the object, maintaining learning structure and order. **Pressing the VR Button**

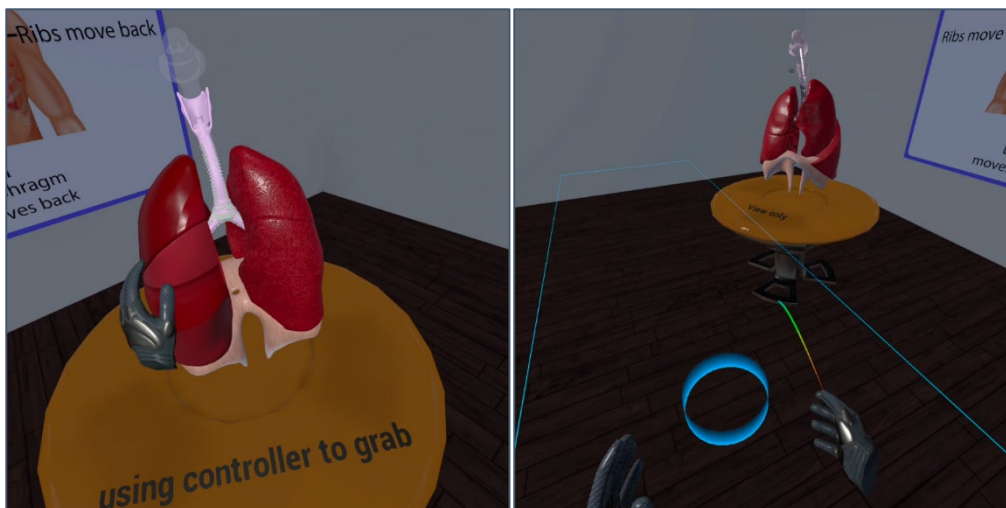


Fig. 4.5 Placing the liver in the original position - teleporting

illustrates the learner initiating a new module segment, again reinforcing interactivity. The educational content scales in detail with **Close-Up View of RBC**,

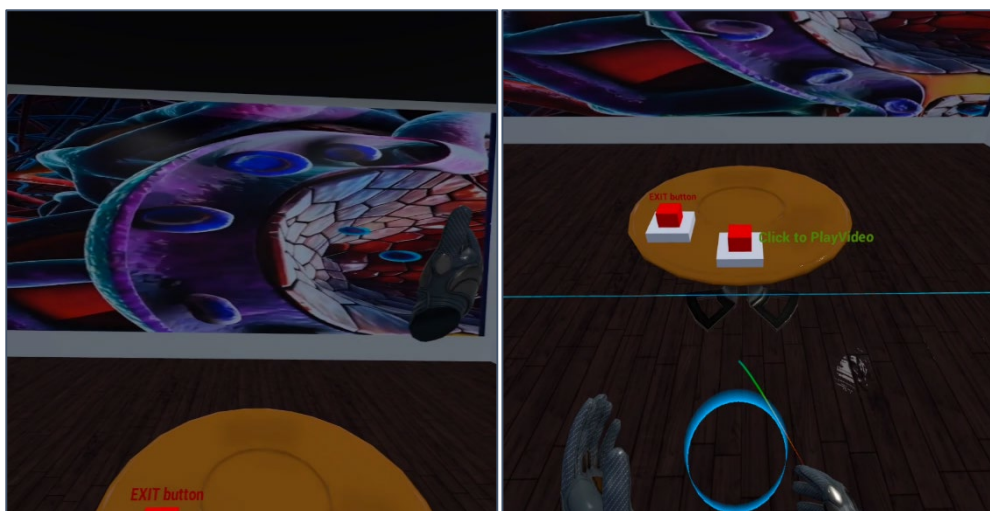


Fig. 4.6 Close up view of RBC in animated VR video

showcasing a magnified red blood cell, essential in oxygen transport. This prepares users for deeper biochemical understanding. The final phase of the journey includes **Teleport to Go Near and See the Video, Video Playing Close to Us, and Video Playing**,



Fig. 4.7 Close up view of the animated VR video

where animations of respiratory functions play on a large virtual screen. These videos serve to visually integrate the anatomical and physiological processes explored in earlier steps. They reinforce key concepts, such as gas exchange, through moving visuals and narrative explanations. Finally, the **Exit Button to Come Out** offers a clear mechanism to end the session, closing the loop of the VR experience. In conclusion, the VR interface effectively scaffolds the learning journey—beginning with orientation, guiding through layered interactivity, and concluding with visual reinforcement and graceful exit. The use of teleportation, hand-based interaction, and rotating anatomical models ensures a

comprehensive, multi-sensory understanding of respiratory anatomy and physiology. This interface sets a high standard for immersive learning tools and demonstrates how VR can revolutionize science education.

4.4 Descriptions of Visual Content from the Experimental Virtual Reality Video on the Human Respiratory System

The experimental VR video designed to teach the human respiratory system uses a sequential, animated format to illustrate the structure and function of respiration, providing learners with a step-by-step understanding of inhalation, gas exchange, and exhalation. The following description captures the visual and instructional essence of the 35 frames extracted from the video.

The opening frames Fig 4.8 establish the anatomical context by showcasing the lungs within the ribcage from various angles.

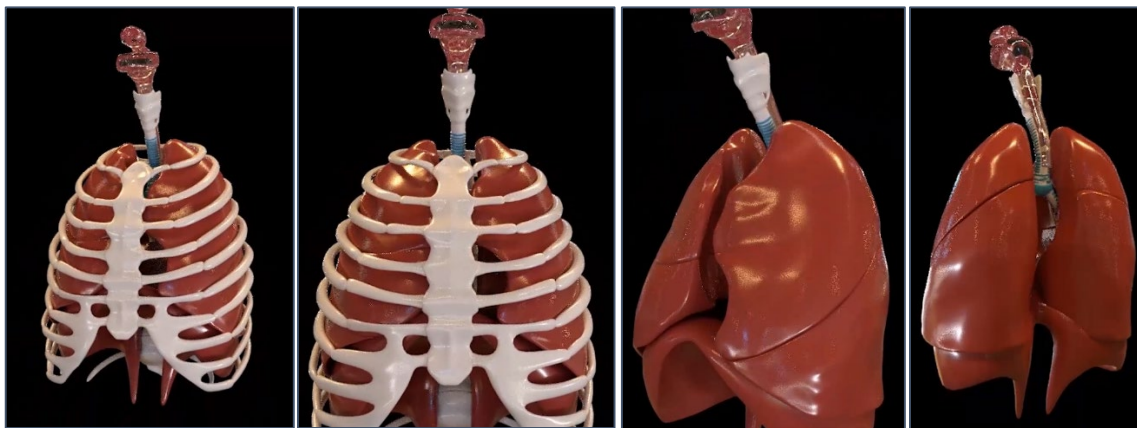


Fig. 4.8 Lungs within the rib cage – Lungs with lobes

The anterior and posterior views help orient the learner spatially while highlighting the different lobes of the lungs. These visuals set a foundational understanding of thoracic anatomy, emphasizing the protective role of the ribcage and the segmentation of the lung lobes.



Fig. 4.9 Air entering through Nostrils

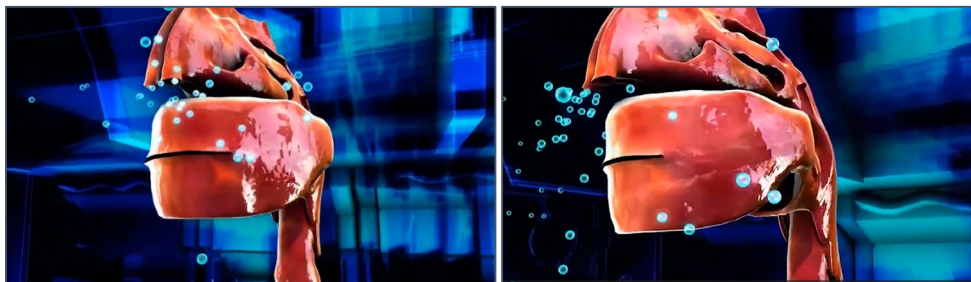


Fig. 4.10 Close up View - Air entering through Nostrils

Transitioning into the respiratory process, Fig. 4.9, Fig. 4.10, show air molecules entering the body through the nostrils and passing through the nasal cavity. These visuals emphasize the filtering, humidifying, and warming functions of the upper respiratory tract. The close-up depictions of the nasal structures support students in grasping the preparatory role this region plays in respiration. Air travels to trachea.



Fig. 4.11 Air molecules travelling to the lungs through Trachea

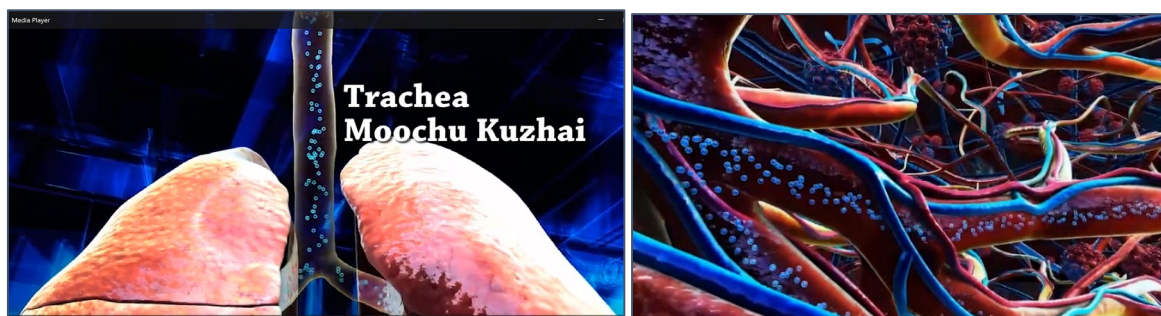


Fig. 4.12 Close up View of Trachea – Fig. 4.12a Air travelling through bronchioles

Fig. 4.11 illustrate the trachea, bronchi, and bronchioles. These animated frames depict the branching of the airways and the directional flow of air into the lungs. By visualizing these tubular structures from within, learners are able to observe how air reaches the deepest parts of the lungs. Fig. 4.12a mark the arrival of air into the bronchioles and Fig. 4.14 shows air travelling to alveoli.

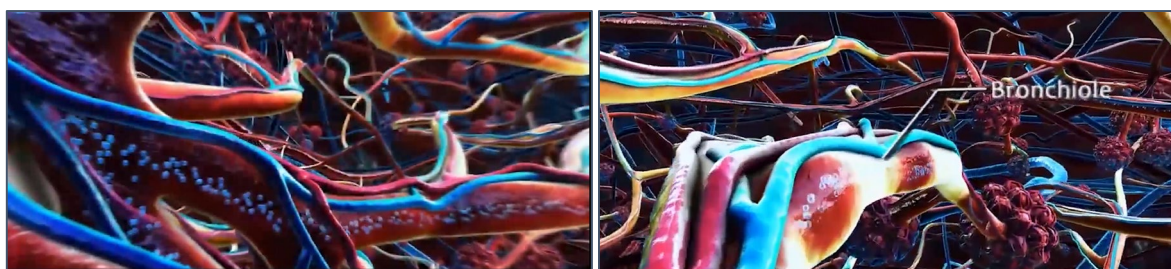


Fig. 4.13 Close up view of bronchioles



Fig. 4.14 Air molecules travelling to Alveoli

These scenes introduce the critical site of gas exchange. The alveoli are shown in 3D form, helping students conceptualize their grape-like structure and multiplicity. This transition from macro to micro anatomy aids learners in understanding how oxygen is distributed throughout the lungs.



Fig. 4.15 Close up view of Alveoli & Capillaries

Fig.4.15 focuses on the capillaries encasing the alveoli. These visuals highlight the thinness of the alveolar membrane and the capillary network essential for gas diffusion. The learner sees, for the first time, the intimate relationship between air-filled alveoli and blood vessels, preparing for the explanation of oxygen transfer. Fig. 4.16 shows the cross section of the alveoli and capillary and hemoglobin inside the capillary is shown in purple color. Fig 4.17 shows the hemoglobin movement in the capillaries. Fig.4.18 demonstrate the process of oxygen molecules diffusing into the capillaries

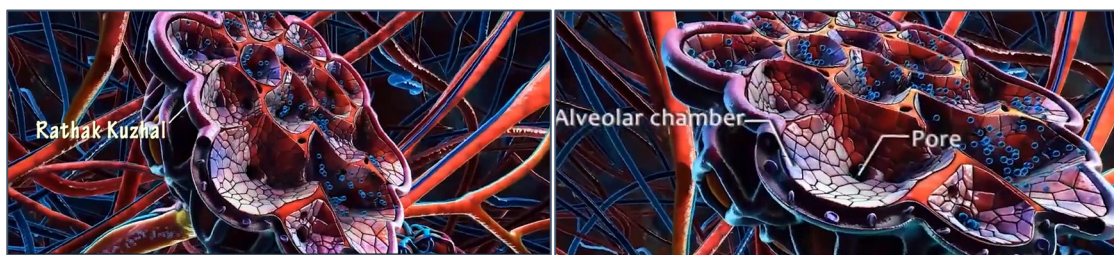


Fig. 4.16 Cross sectional view of alveoli and capillary

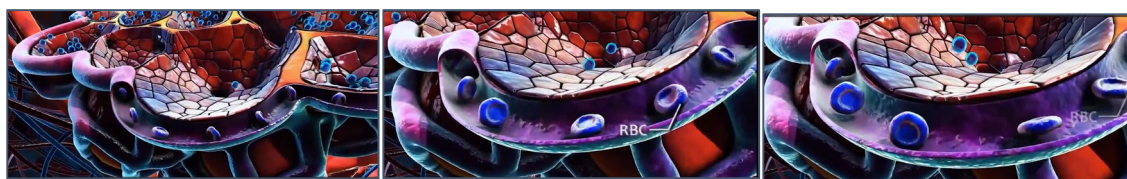


Fig. 4.17 Haemoglobin movement in the capillary



Fig. 4.18 Oxygen getting diffused to the capillary

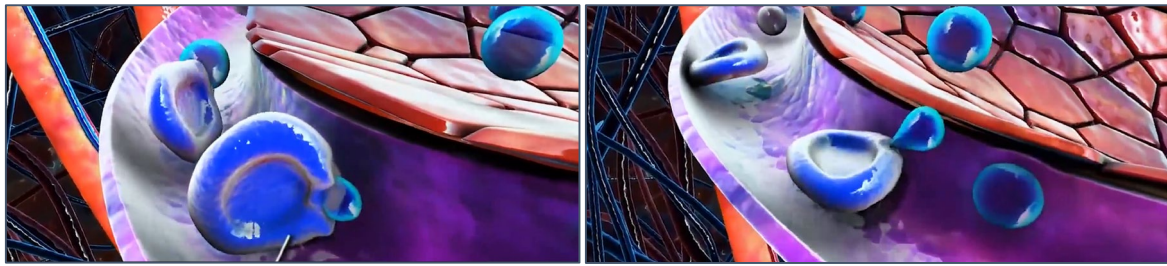


Fig. 4.19 Oxygen getting absorbed by haemoglobin

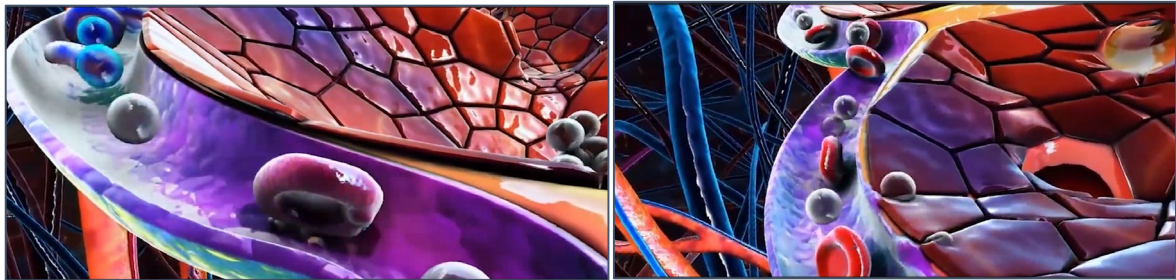


Fig. 4.20 Oxygenated haemoglobin – Oxyhaemoglobin

Fig. 4.19 and Fig. 4.20 depicts oxygen combining with hemoglobin to form oxyhemoglobin which is shown in red color.

Oxyhemoglobin is visually symbolized by a change in color from blue (deoxygenated) to red (oxygenated). The animation reinforces the concept of oxyhemoglobin formation and the systemic distribution of oxygen via the bloodstream. The gradual movement and multiple close-up frames ensure retention of this vital mechanism.

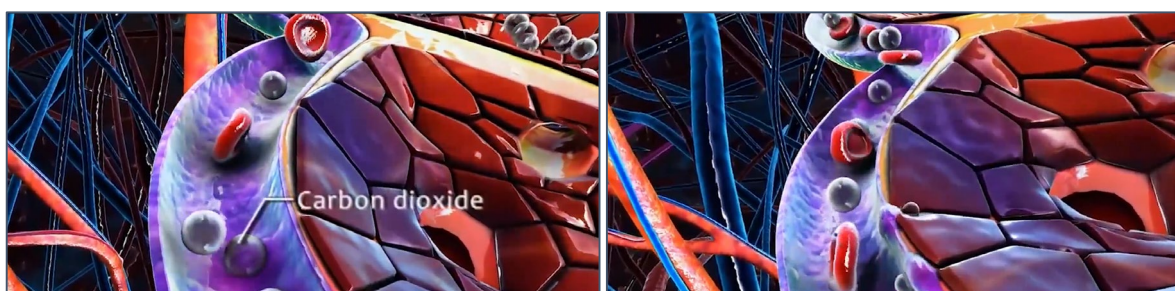


Fig. 4.21 Carbon dioxide is getting released

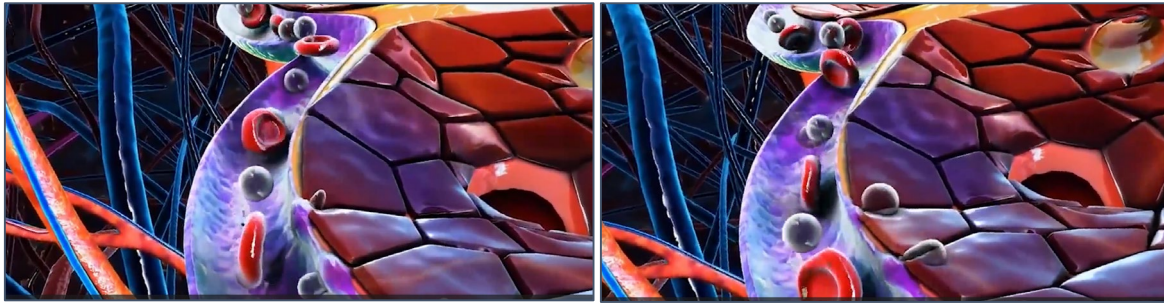


Fig. 4.22 Carbon dioxide through diffusion moves to alveoli

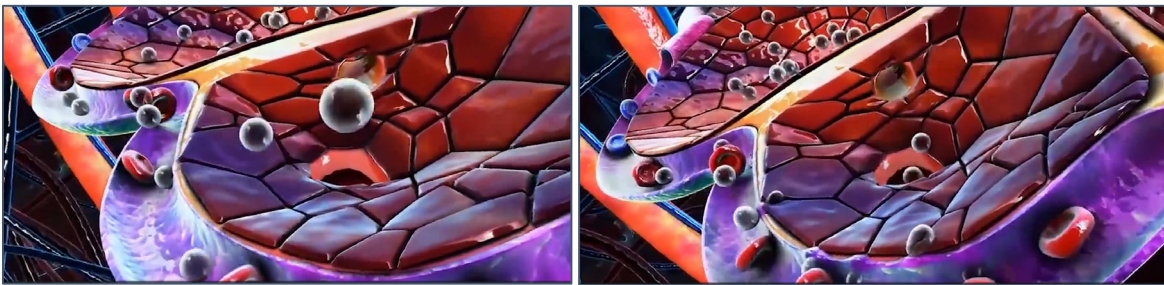


Fig. 4.23 Carbon-di-oxide moves to alveoli

In Fig. 4.22 to Fig. 4.23 Carbon dioxide gets released and get into the alveoli through diffusion method.

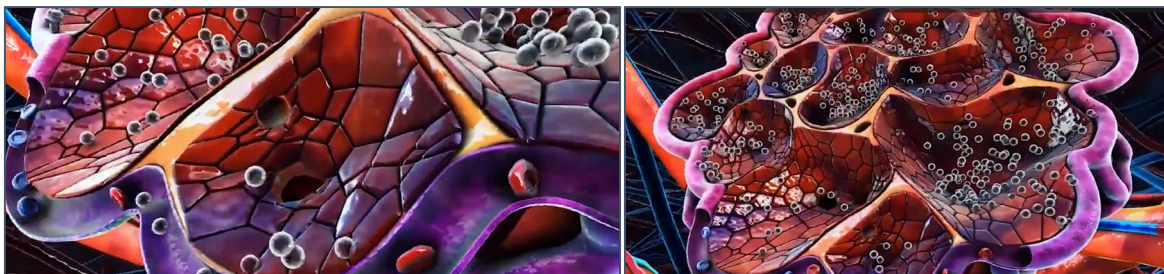


Fig. 4.24 Carbon-di-oxide in alveoli



Fig. 4.25 Carbon-di-oxide travelling back to bronchiole

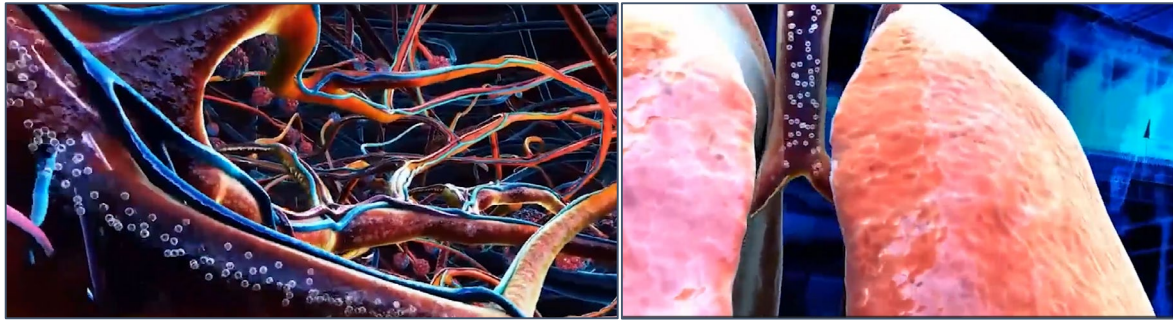


Fig. 4.26 Carbon-di-oxide travelling through bronchiole to Trachea

Fig. 4.24, Fig. 4.25, Fig. 4.26 shows the released carbon dioxide is back to the alveoli and moves to bronchioles and then to bronchus , to trachea and finally goes out through the nose.



Fig. 4.27 From the Trachea Carbon-di-oxide getting released through the nose



Fig. 4.28 Overall view of carbon dioxide getting released out

Carbon dioxide takes the reverse pathway of travel from the alveoli through the bronchioles and trachea, and out through the nostrils shown in Fig.4.27, Fig.4.28. These frames bring the full respiratory cycle to a close, offering a comprehensive visual of the system's functionality.

The visual sequencing in the VR video integrates anatomical structure with physiological function. Each step is represented using immersive 3D animations, enhancing spatial awareness and molecular comprehension. The learning experience is scaffolded—beginning with gross anatomy and narrowing down to the micro level—ensuring that students grasp both the mechanical and chemical dimensions of respiration. The use of motion, repetition, and

perspective shifts promotes a multisensory learning approach ideal for middle school science education. The video's clear visual logic and pedagogical design underscore the potential of VR as a transformative tool in biology instruction.

Discussion:

This discussion centers on an experimental Virtual Reality (VR) application designed to enhance middle school students' understanding of the human respiratory system. Developed over approximately one year at an estimated cost of ₹5 lakhs, this immersive learning tool aims to transcend traditional pedagogical limitations by offering a highly interactive and visually rich educational experience.

The VR environment initiates with a familiar headset home screen, leading users into a custom-built application named "MyProject," powered by Unreal Engine. Upon entry, students are immersed in a virtual classroom featuring a realistic wooden floor, where virtual hands serve as intuitive controllers. A prominent interactive platform presents clear options, such as "Press the Button to open next level," guiding users through the learning module⁴.

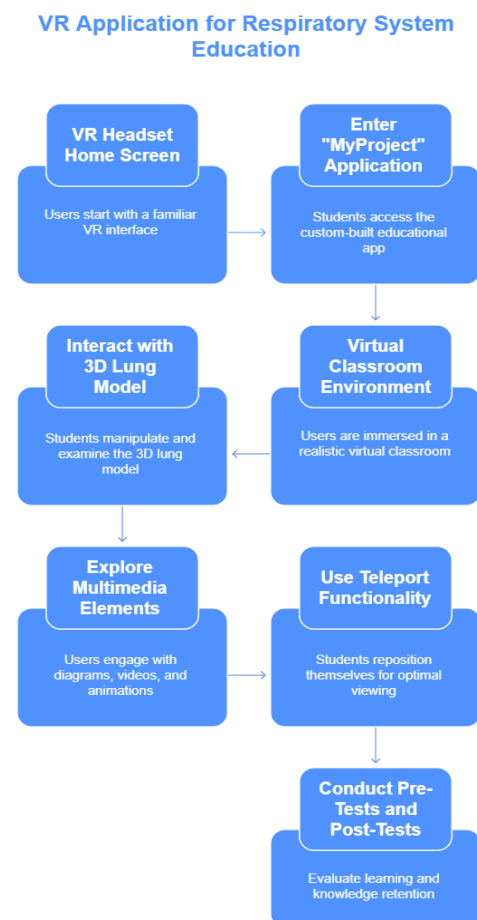


Fig. 4.29 VR application for respiratory System Education

A core feature of the application is the meticulously designed 3D model of the human lungs. Students can virtually interact with this model by picking it up, rotating it, and examining its structure closely, a capability that directly addresses the study's objective of bridging theoretical understanding with hands-on exploration. Furthermore, the application integrates various multimedia elements: detailed anatomical diagrams of the respiratory system, animated videos illustrating the complexities of the system, and close-up views of micro-level processes such as gas exchange at the alveolar capillary membrane. Visualizations include air molecules traveling through the respiratory tract, oxygen absorption by red blood cells, and carbon dioxide expulsion, offering a dynamic and clear representation of physiological functions.

The user experience is further enhanced by functionalities like "teleport," allowing students to reposition themselves or objects for optimal viewing of content, including the 3D models and embedded videos. This interactive design is integral to the broader research methodology, which includes Pre Tests, Post Tests, and a retention test, alongside qualitative data collection from educators, to comprehensively evaluate the VR tool's impact on learning and knowledge retention¹.

This experimental VR video represents a significant step towards leveraging immersive technology in science education. By combining detailed 3D models, dynamic animations, and intuitive interactive controls, the application offers a compelling and effective platform for understanding complex biological systems. Its structured integration into a research framework underscores its potential to not only engage students but also to demonstrably improve their long-term comprehension and retention of scientific concepts.

4.5 Analysis of Sample

Overview

Analysis and interpretation are fundamental stages in the research process. The objective of the analysis is to organize, classify and summarize the obtained data to enhance comprehension and interpretation, thereby addressing the questions that initiated the research. Interpretation involves seeking the overarching significance of the results. Analysis is incomplete without interpretation and interpretation cannot occur without analysis; hence, both are interdependent. This chapter presents a comprehensive analysis of the acquired data in accordance with the previously outlined objectives. Hypotheses were tested based on the study's findings and

interpretations and conclusions were derived. This chapter presents the statistical methodologies employed for analysing the data collected in the current study, namely Descriptive Analysis and Inferential Statistics.

4.5.1 Frequency Test:

Age:

The respondents were predominantly 13 years old (98%), with only a small portion aged 14 (2%). This indicates a uniform age group, which contributes to consistency in cognitive levels and learning maturity. Such homogeneity enhances the reliability of comparing perceptions and experiences with VR-based learning. It also reduces age-related variance in interpretation and adaptation to technology.

Class:

All participants belonged to the 8th standard, ensuring that they had equal academic exposure and were at the same curricular stage. This consistency supports focused evaluation of VR in relation to their specific science lessons. It eliminates any grade-based differences in understanding or prior knowledge. The findings thus reflect the experience of middle school learners.

Table 4.1 Gender

Question	Response	Number	Percent (%)
Gender	Male	126	63
	Female	74	37

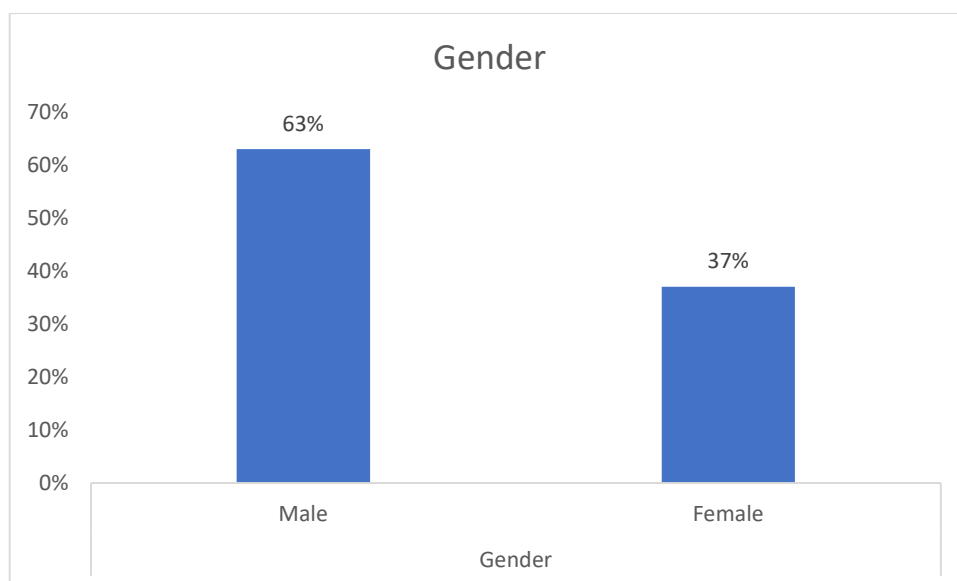


Fig. 4.30 Responses with respect to Gender

With 63% males and 37% females, the sample had more boys than girls, though both genders were reasonably represented. This allows for basic gender-based comparisons while maintaining balance. The higher male presence may slightly influence the outcome, especially in technology-based interest areas. Nevertheless, both groups contributed meaningfully to the data.

4.5.2 Descriptive Analysis of Sample:

Percentage analysis is one of the statistical measures used to describe the characteristics of the sample or population in totality. Percentage analysis involves computing measures of variables selected for the study and its findings will give easy interpretation.

Table 4.2 Frequency Distribution of Students by Gender

Gender (Chalk & Board, VR)		
Gender	Frequency	Percent
Male	242	60.50%
Female	158	39.50%
Total	400	100%

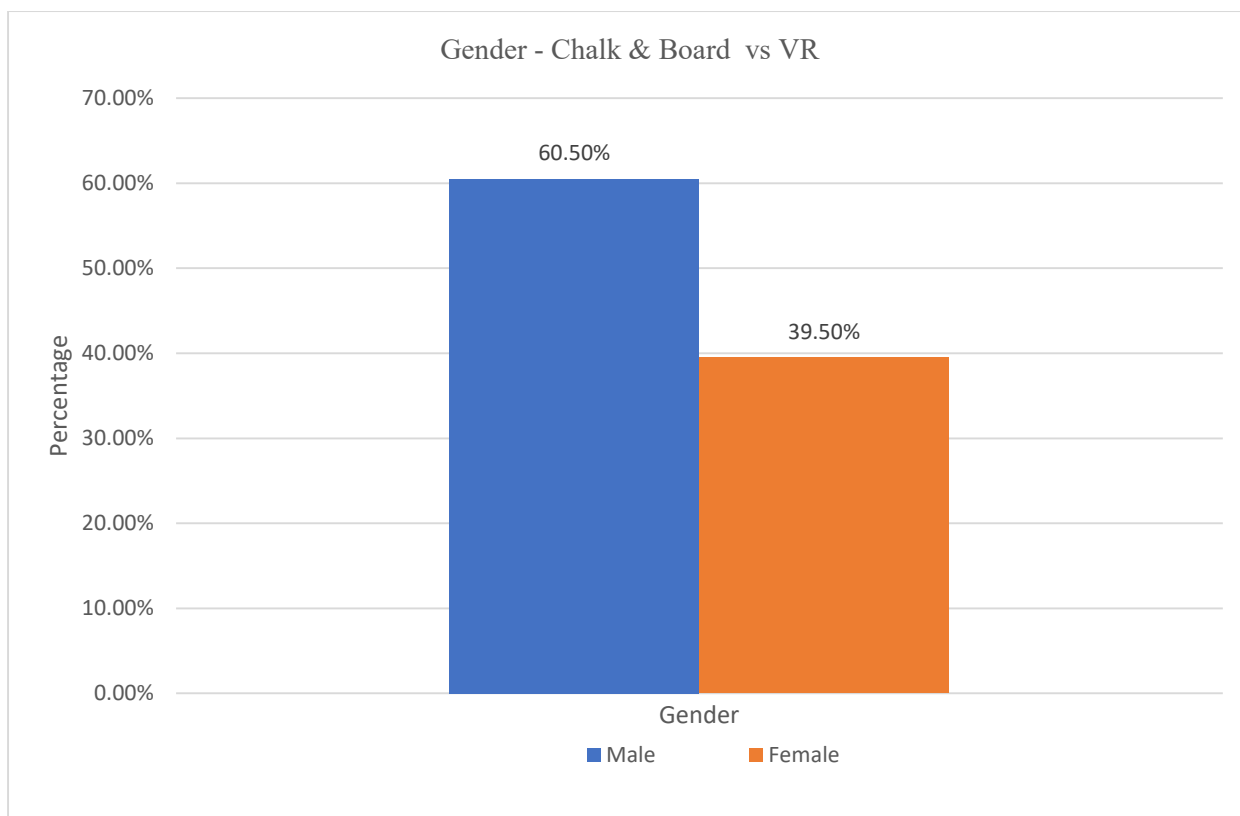


Fig. 4.31 Bar diagram representation of Chalk & Board & VR Student's Gender Percentage

From the above table 60.50 % of students participated in the survey is male and 39.50 % of students participated in the survey is female. The maximum number of participations being male students the reason being still the overall percentage of boy children in school is more compared to female children. A total of 400 students participated, 200 in each group catering from different schools

Table 4.3 Frequency Distribution of students - Zone

Zone	Frequency	Percent
North Chennai	144	36%
Central Chennai	142	35.50%
South Chennai	114	28.50%
Total	400	100

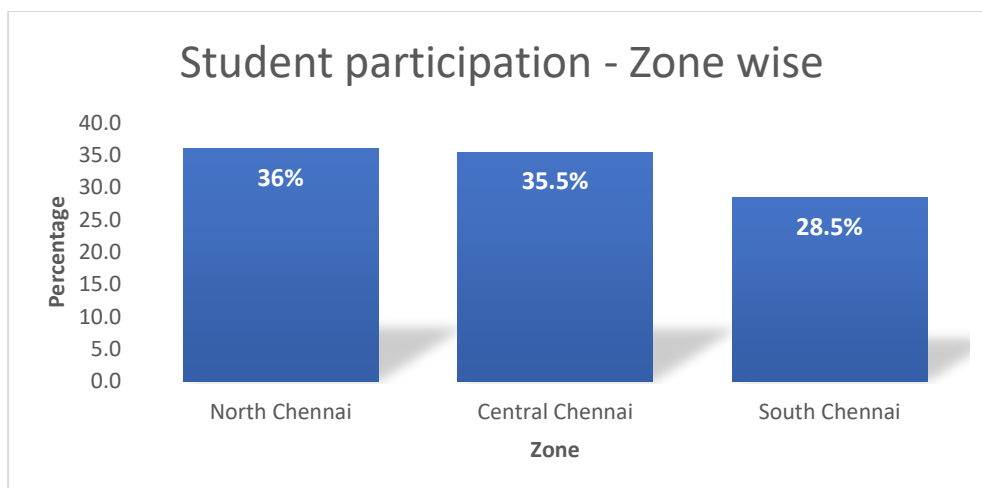


Fig. 4.32 Bar diagram representation of Zone wise student participation

From the above table, 36% of the total data is from North Chennai, Central Chennai contributed to 35.50 % of the total data and South Chennai contributed to 28.50% of the total data, the frequency being 72 in each group totaling to 144 students in North Chennai and 71 in each group totaling to 142 students in Central Chennai and 57 students in each group totaling to 114 students in South Chennai.

4.6 Pre Test Analysis

4.6.1 Tabulated Data & Analysis of Pre-test chalk & Board, Pre-test VR

Pre Test of Chalk & Board and Pre Test of VR scores are analyzed to find the understanding level of the students regarding the subject respiratory system (Objective 1: Examine the current understanding and knowledge levels of students regarding the subject taught through conventional methods when compared to the understanding level of the students after the usage of VR)

Table 4.4 Student's Pretest Achievement Percentage %

Questions	Pre Test - Chalk & Board <i>Correct Answer</i>	Pre Test - VR <i>Correct answer</i>
Q1. Haemoglobin in the blood combines with oxygen to form oxyhaemoglobin	29%	73%
Q2. Carbon-di-oxide in the blood, which is released by the tissues, reaches the alveoli through diffusion method	26%	33%
Q3. Carbon-di-oxide from the blood reaches the alveoli and goes out from the body through the nasal passage.	31%	53%
Q4. The alveoli help in the exchange of oxygen and carbon-di-oxide	26%	58%
Q5. Lungs is an organ found in the thoracic cavity	25%	28%
Q6. The air that we breathe through the nose goes first into the Trachea.	33%	54%
Q7. Trachea divides into two bronchi	72%	77%
Q8. The bronchus again divides into several bronchioles and finally ends in alveoli	30%	38%
Q9. The alveoli is surrounded by blood vessels - capillaries	79%	81%
Q10. The oxygen in the air goes till the alveoli and from there through diffusion reaches the capillaries	38%	27%

The achievement percentage in table 4.3.3 depicts the marks scored by the students of conventional chalk & board method on Pre Test and Post Test and Virtual reality method on Pre Test and Post Test. Percentage wise correct response is given along with questions. The same 10 questions only were administered to both chalk & board and VR, Pre Test and Post Test. The statistical analysis is given below.

4.6.2 T-Test: Pre Test of Chalk & Board Vs Pre Test of VR

HYPOTHESIS 1:

Null Hypothesis H_0 : There is no significant difference between the Chalk & Board and VR learning with respect to the understanding level of the students

Table 4.5 T-Test: Pre Test of Chalk & Board Vs Pre Test of VR

T Test				
Method	Mean	SD	t Value	P Value
Chalk and board	3.89	1.559	6.356	<0.001**
Virtual Reality	5.05	2.043		

Note: ** denotes significance at 1 % level

* denotes significance at 5 % level

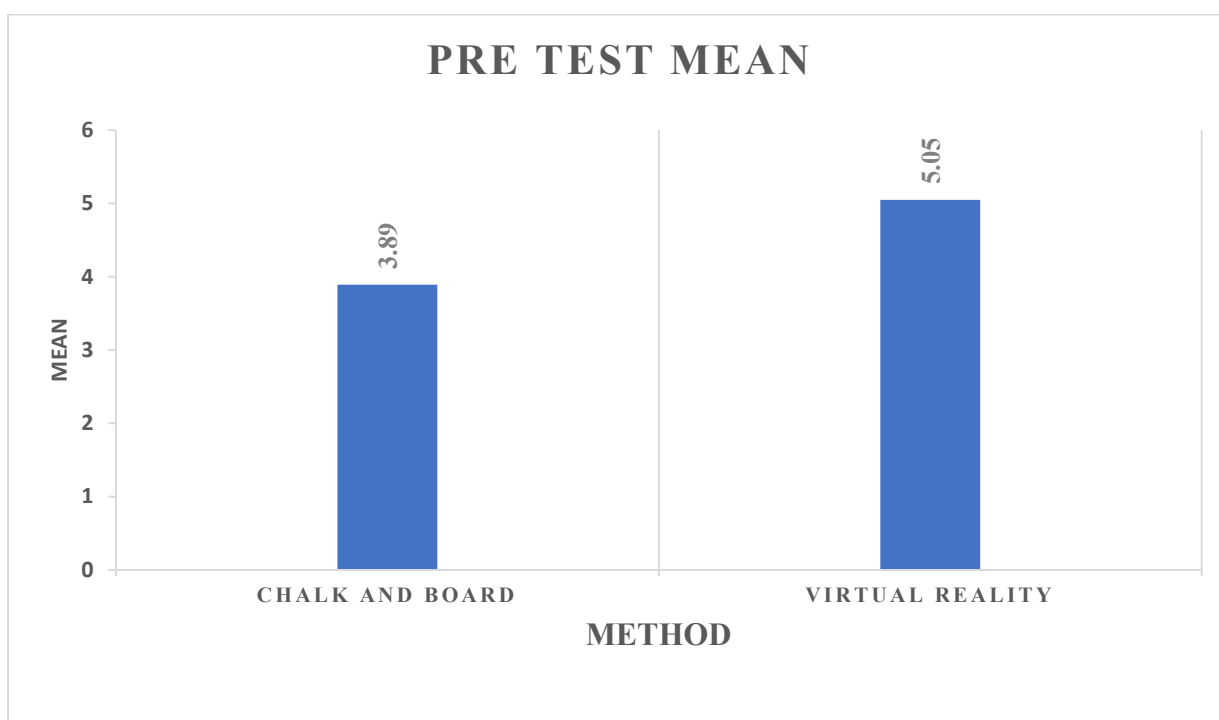


Fig. 4.33 Bar diagram representation of MEAN value of Pre Test of chalk & board and VR

Objective 1: Understanding Level

This objective was designed to assess and compare students' understanding of the respiratory system when taught through two different instructional methods: traditional chalk and board and Virtual Reality (VR). Initially, a class was conducted using the conventional chalk and board method. Following the session, students were administered a short pre-test consisting of

multiple-choice questions. Each response was evaluated with a scoring system where a correct answer was awarded 1 point and an incorrect answer was given 0. This allowed the researchers to gauge students' comprehension through traditional instruction.

Next, the same topic was taught using an immersive VR model developed specifically for this study for a different group of students. After the VR-based lesson, students were again given the same pre-test questions. Their responses were similarly evaluated. This provided a direct comparative measure of the effectiveness of both instructional approaches in enhancing immediate knowledge acquisition. ***Reject the null hypothesis at a significance level of 1 %***, the p value being less than 0.001 indicating that the students who learnt through VR were able to understand better when compared to the students who learnt the subject through conventional method. This indicates that though teacher taking classes are good, students understand more effectively due to the visuals and animations making the subject easy to understand. The results also confirm that students taught using VR performed better on most items, indicating that VR facilitated a higher level of initial understanding of complex concepts such as gas exchange, airflow and lung structure.

4.6.3 Gender Specific Correct Response in Pre Test of Chalk & Board

HYPOTHESIS 2:

Null Hypothesis H_0 : There is no significant difference in the total positive responses between male and female students with respect to the understanding level when taught through conventional method

Table 4.6 Gender Specific Responses in Pre Test of Chalk & Board

Pre Test - Chalk & board	Gender			
	Male		Female	
	Yes	No	Yes	No
Q1	34	87	24	55
Q2	35	86	17	62
Q3	43	78	60	19
Q4	28	93	24	55
Q5	27	94	23	56
Q6	42	79	24	55
Q7	87	34	57	22
Q8	29	92	31	48
Q9	101	20	57	22
Q10	44	77	32	47

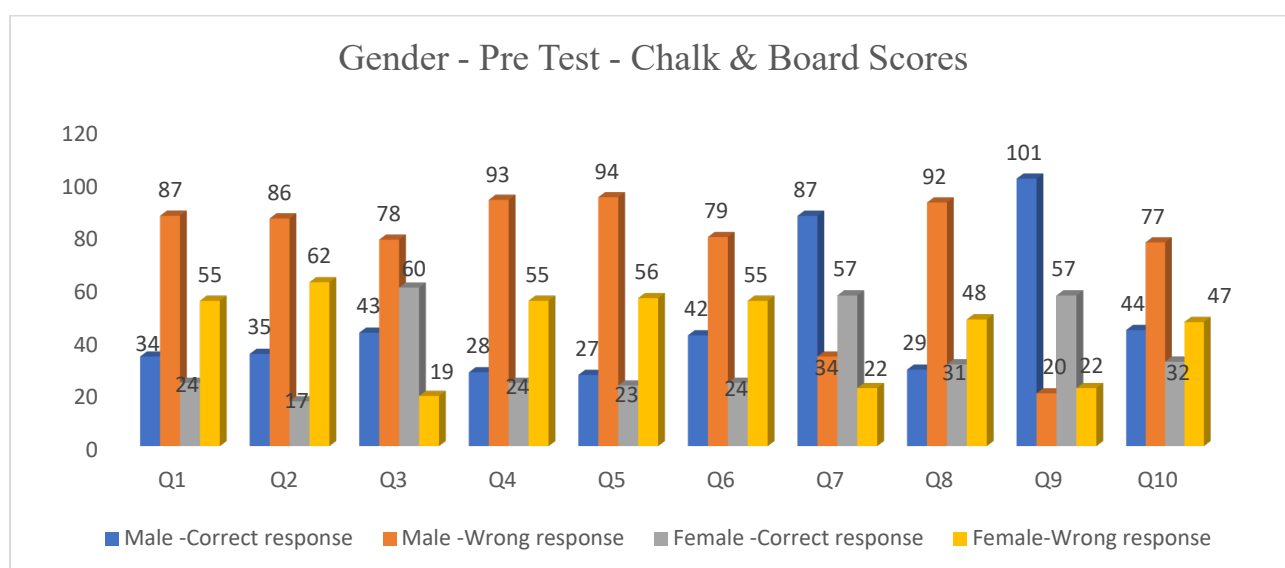


Fig. 4.34 Gender specific Pre Test Chalk & Board Scores in Pretest

Q1: Understanding level for Q1 when learnt through Conventional method.

Out of 200 students who attended the conventional method of teaching, for Q1 only 29 % (34 male; 24 female) of the students correctly identified the function of hemoglobin, while a majority of 71 % responded incorrectly. This result is concerning as it reflects a substantial lack of understanding of a fundamental concept in respiratory physiology. Female students performed slightly better in terms of the number of correct answers, yet both genders demonstrated low comprehension levels. With just 29% of students answering correctly, this

concept may not have been effectively conveyed during instruction. Given that the role of hemoglobin in oxygen transport is central to understanding the circulatory-respiratory relationship, targeted remedial teaching is necessary. Interactive visualizations, hands-on models, or virtual reality experiences could reinforce the biological significance of hemoglobin. Overall, this finding signals a need to revisit foundational biology concepts and implement engaging strategies that address both male and female learners equally.

Q2: Understanding level for Q2 when learnt through Conventional method.

Only 26 percentage (35 male, 17 female) of the total students correctly answered this question, 74 % gave incorrect responses. Despite this, the overall accuracy rate of 26% is very low. This suggests that students struggle to understand how carbon dioxide is transported from body tissues to the lungs. Male students performed better when compared to female students. The disparity between genders may be attributed to differences in comprehension or teaching engagement, but the general low performance implies inadequate conceptual clarity. The physiological process involving the circulatory system and alveoli should be reinforced using process diagrams, animations, or step-by-step breakdowns of the respiratory exchange. This concept is crucial for understanding gas transport and respiration and its poor grasp among students suggests an urgent need for curriculum reinforcement. Improving clarity here will enhance broader understanding of respiratory function.

Q3: Understanding level for Q3 when learnt through Conventional method.

For the question Q3, 51 % (43 male, 60 female) of students answering correctly 49 % answering incorrectly. This gives a 51% accuracy rate overall, indicating medium understanding of the mechanism by which carbon dioxide exits the body. Female students demonstrated stronger performance in both raw numbers and proportions. Interestingly, females had more correct answers than wrong ones, suggesting that they get more clarity about the exhaled gas passage. Despite the gender discrepancy, the results imply that students are more familiar with the basic exhalation route than with gas transport processes. Since over 49% got it wrong, nearly 50 % of the students were able to understand the travel of air after oxygenation, also since it is a normal process of exhalation reinforcing the anatomy of the respiratory tract and the process of expiration would be beneficial.

Q4. Which helps in the exchange of oxygen and carbon-dioxide (alveoli or Bronchi).

Out of 200 students, only 26 % (28 male, 24 female) gave the correct answer, while 74% responded incorrectly. With just 26% accuracy, this result highlights a severe conceptual gap in students' understanding of how oxygen and carbon dioxide are exchanged in the body. Although female students outnumber males in the correct responses, the performance across both genders is poor, indicating widespread confusion. This concept is central to respiratory physiology, often involving the role of alveoli and capillaries. Students may not fully grasp the micro-level interactions involved in gas exchange. To address this, educators should employ more concrete representations, such as 3D animations or VR-assisted walkthroughs of alveolar gas exchange. The data reveals a critical learning deficiency that could hinder understanding of larger biological systems, necessitating an immediate pedagogical intervention with tools that promote clarity and retention.

Q5. Lung is an organ found in which cavity of the body.

Only 25% (27 male, 23 female) students correctly identified the location of the lungs, while a staggering 75% gave incorrect answers. This yields a very low accuracy rate of just 25%, revealing a significant lack of basic anatomical knowledge. Given that this is elementary information often taught at the primary level, the results are concerning and suggest a failure in reinforcing fundamental human biology concepts. Female students performed slightly better in absolute numbers than male students. This misunderstanding may stem from rote memorization without conceptual clarity. Reinforcing anatomy with labeled diagrams, practical experiments, or interactive models can significantly enhance retention. As the lungs are central to multiple physiological systems, this finding signals a need for foundational revision. Correcting these gaps is essential before progressing to more complex respiratory functions. Thus, educators must revisit these basic lessons with engaging and repetitive teaching strategies.

Q6. Understanding level for Q6 when learnt through Conventional method.

This question was answered correctly by 33 % (42 male, 24 female) students, while 66% responded incorrectly. The accuracy rate of 33% indicates limited understanding of the basic path of air after it enters the nose. While male students slightly outperformed females in terms of raw numbers, the overall performance from both groups is subpar, reflecting weak spatial visualization of the respiratory tract. Teaching aids such as airflow models or virtual

simulations showing air movement from nose to lungs could help clarify this sequence. This concept is crucial to understanding the mechanics of breathing and the respiratory system's structure. The results call for improved visual and experiential learning methods. Given that two-thirds of students answered incorrectly, this topic requires immediate pedagogical attention to bridge the learning gap and strengthen students' conceptual understanding of air conduction in respiration. Chi-square value being 0.405 and p value = 0.524, we accept the null hypothesis stating that there is no significant difference between the male and female students with respect to understanding level of question 6

Q7. Trachea divides into how many bronchi.

This concept was the best understood among the ten, with 72 % (87 male, 57 female) of students giving the correct answer and only 28% getting it wrong. The 72% accuracy rate indicates that most students understood how the trachea branches into bronchi, likely due to visual representation in textbooks and classroom charts. Both male and female students answered it correctly indicating that there is no disparity in gender in understanding about how the trachea branches out. The trachea's division is a basic anatomical fact and the high success rate suggests effective instructional strategies around this topic. Given its clarity, this concept can be used as a foundational base to teach more complex branching structures like bronchioles and alveoli. While the gender difference is minor, targeted reinforcement can help bring all students to the same level of understanding. This strong performance shows that foundational respiratory anatomy can be well taught with the right resources.

Q8. The bronchi divide into several bronchioles and finally ends in

Out of 200 students Only 30% students (29 male, 31 female) correctly identified the destination of bronchioles, while 70% responded incorrectly. The overall 30% accuracy rate reflects a weak understanding of the anatomical structure of the respiratory tree. Interestingly, females outperformed males despite their smaller sample size, with 39.24 % of the total female strength answering correctly compared to only 23.93% of males. This suggests that male students particularly struggle with remembering or conceptualizing the terminal parts of the bronchial tree. The result points to a need for more effective teaching strategies that clarify the sequence from bronchus to bronchioles to alveoli. Use of 3D lung models or interactive flow diagrams may help. Since understanding alveolar connections is key to learning gas exchange, addressing this foundational confusion is crucial. The results call for targeted review and

reinforcement, especially among male students, to ensure accurate anatomical mapping of the respiratory system.

Q9. The alveoli is surrounded by blood vessels - capillaries

79% of students (101 male, 57 female) correctly answered this question, while only 21% gave incorrect responses. With an impressive 79% accuracy rate, this concept seems to be well understood across both genders. Male students performed slightly better proportionally, with 83.47% correct responses compared to 72.15% of females. This topic may have been effectively taught using diagrams or interactive tools that emphasize the capillary-alveoli relationship, a crucial component in gas exchange. Given its physiological importance, this strong performance is encouraging. It also shows that when content is presented clearly and reinforced well, students can develop a strong grasp of even complex microscopic structures. The relatively small error margin suggests this concept can be used to scaffold deeper learning on diffusion and respiratory functions. Continued reinforcement through applied examples and visual aids will help maintain and improve this understanding.

Q10. The oxygen in the air goes till the alveoli and from there through diffusion reaches capillaries or heart

This question saw 38% (44 male, 32 female) correct answers and 62% incorrect responses, with an overall 38% accuracy rate. Female students outperformed males proportionally, with nearly 40.51% correct responses versus 36.36 % from males. The concept involves understanding the diffusion of oxygen from alveoli to blood capillaries, which may be too abstract for many students without visual or tactile reinforcement. This moderate performance shows that while some grasp the process, many remain confused. Misconceptions may arise from mixing up airflow and diffusion pathways. Interactive simulations that trace oxygen molecules or real-life analogies could help students visualize this better. As this concept is critical for understanding how oxygen enters the bloodstream, targeted teaching is necessary. With a clearer instructional focus and gender-sensitive strategies, the comprehension gap can be bridged. The current data suggests this concept is moderately understood but needs improvement, especially among male students.

The overall Gender-wise Findings on the Pre Test of Conventional Method data reveals there is no difference between the male and female students with respect to the understanding level

when taught through conventional method chalk & board except hence we *accept the null hypothesis* except for Q8, where female students performed better than the male students.

4.6.4 Error % -Pre Test Chalk & Board vs Pre Test VR

HYPOTHESIS 3:

Null Hypothesis H_0 : There is no significant difference in the error percentage between the Pretest Chalk & board scores and Pre Test VR scores

Table 4.7 Pre Test Chalk & Board & Pre Test VR – Error %

Q. No	Pre-Test Chalk & Board Error %	Pre-Test-VR Error %
Q1	71%	27%
Q2	74%	67%
Q3	69%	47%
Q4	74%	42%
Q5	75%	72%
Q6	67%	46%
Q7	28%	23%
Q8	70%	62%
Q9	21%	19%
Q10	62%	73%

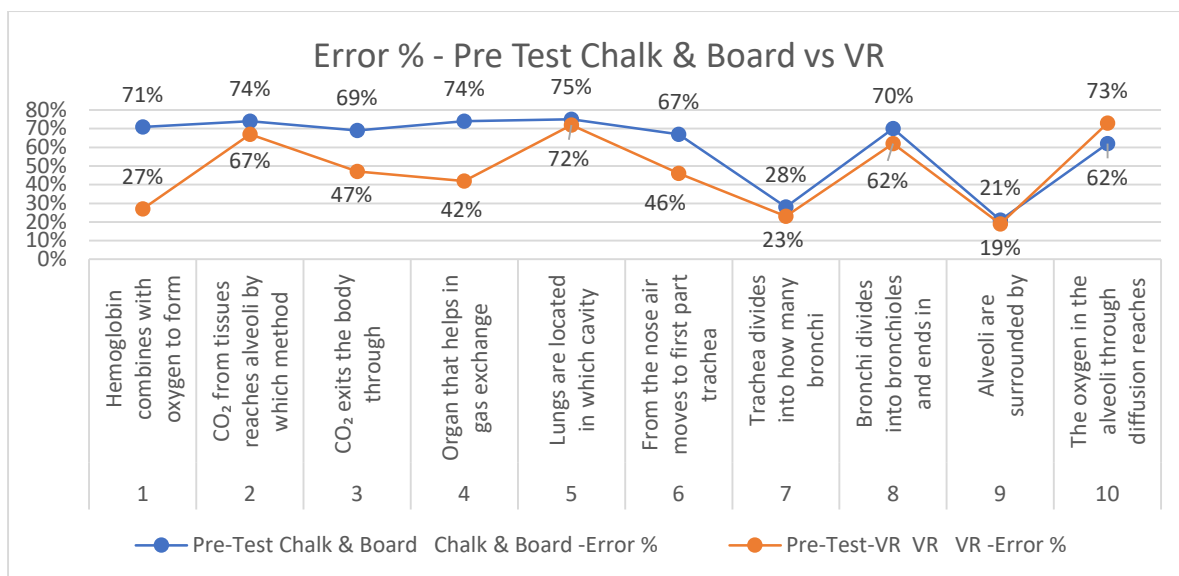


Fig. 4.35 Error % - Pre Test Chalk & Board vs Pre Test VR

The error Percentage of Pretest of conventional method – Chalk & board and the error percentage of VR shows that the chalk & board students confirmed more error meaning, their *understanding level in the subject learnt through conventional method is low when compared to the VR method*, where VR method learning shows less error percentage, except for the last question, oxygen in the alveoli through diffusion reaches the heart or capillaries. The cause of this could be the voice over in the VR module, which says that the purified oxygen reaches the heart, the students would have taken this as a point while listening and there could be a possibility of misunderstanding because of the voice over. For all the other questions VR Pre Test proves that students were able to understand it better than the Chalk & Board conventional method.

Table 4.8 T-Test on Pretest of chalk& board and VR

T Test - Pretest				
Method	Mean	SD	t Value	P Value
Chalk and board	3.89	1.559	6.356	<0.001**
Virtual Reality	5.05	2.043		

T test on Pre Test of Chalk & Board and VR results indicates that VR students understanding level is more mean = 5.05 when compared to the chalk & board mean = 3.89 and the p value is less than 0.001 signifies that the *null hypothesis is rejected at a significance level of 1 %* confirming that VR students understanding level on the subject respiratory system is more when compared to the chalk & board students.

4.6.5 Paired Sample T test – Pre Test of Chalk & board vs Post Test of Chalk & board

HYPOTHESIS 4

Null Hypothesis H_0 : There is no significant difference between the understanding and retention level among students when taught through Chalk & Board

Table 4.9 Paired Sample T test – Pre Test of chalk & board vs Post Test chalk & board

Paired Samples Statistics

Tests	Mean	SD	t value	P value
Pre Test	3.89	1.559	2.260	0.025*
Post Test	3.55	1.403		

Note: * denotes significance level at 5 %

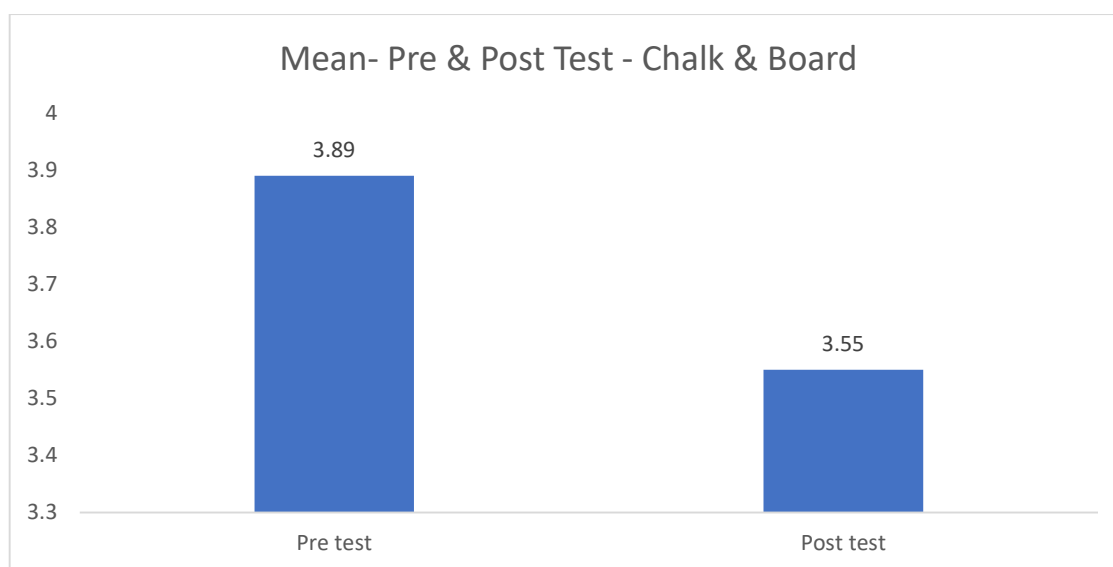


Fig. 4.36 Bar diagram representation of MEAN value of Pre Test vs Post Test of chalk & board

Pre Test was conducted among the students through the structured questionnaire immediately after the class teacher took the subject about respiratory and the marks have been evaluated. To assess long-term retention, the same set of questions was re-administered to the same group of students after two months. This post-test aimed to measure the retention level of the content

taught traditional method. The responses from pre-test and post-test were analyzed to determine the comparative effectiveness of traditional methods of teaching in understanding and enhancing memory retention. Paired test reveals that VR Post Test mean value is much less than the VR Pre Test mean value. Post Test mean = 3.55 and the Pre Test mean = 3.89. Paired Sample T-test signifies the students understanding and retention level, immediately after the class was taken and after a period of two months. Based on the analysis, ***the null hypothesis is rejected at a significance level of 5 %***, at a P value of 0.025, which indicates that there is a significance difference in the both the understanding and the retention level of the conventional chalk & board students, the retention level has significantly reduced meaning that the students were not able to recollect the subject properly after a period of two month when compared to the results of the pretest taken immediately after the session. Traditional method uses, chalk & board alone in corporation schools, where the lung has been drawn on the board, which doesn't help the students to recollect the subject much after a period of time.

4.6.6 Error % - Pre Test of Chalk board and Post Test of chalk & board

Table 4.10 Error % - Pre Test of Chalk board and Post Test of chalk & board

Q.NO	Pre-Test -Chalk & board	Post-Test Chalk & board
	Wrong (%)	Wrong (%)
Q1	71%	76%
Q2	74%	77%
Q3	69%	70%
Q4	74%	76%
Q5	75%	76%
Q6	67%	46%
Q7	28%	24%
Q8	70%	77%
Q9	21%	21%
Q10	62%	62%

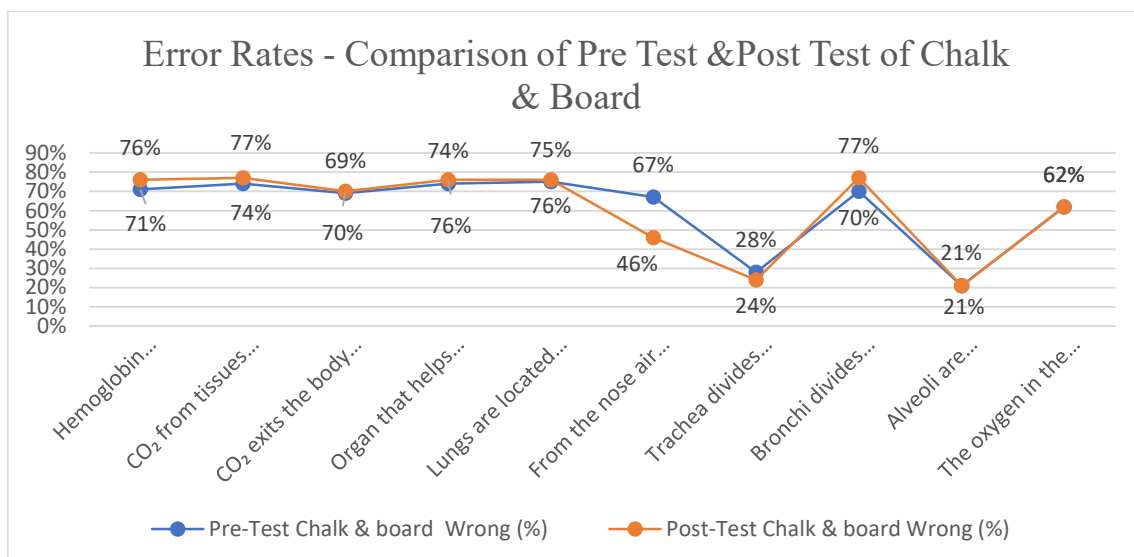


Fig. 4.37 - Error Rates - Pre Test Chalk & Board Vs Post Test of Chalk & Board

Despite a statistically significant rise in post-test results following traditional training, the overall improvement in retention was negligible. The enhancement in mean scores from 3.5 to 4.55 indicates that although students demonstrated improved performance on certain problems immediately post-instruction, their retention of essential ideas related to the respiratory system remained inadequate. This corresponds with the discovery that several students' scores were static (e.g., 21% → 21%, 62% → 62%), while in certain instances, there was a fall (e.g., 28% → 24%).

Students' low performance on the chalk-and-board pretest indicates that they struggled to grasp many of the ideas covered in class, particularly those pertaining to internal parts of the respiratory system. Based on the error rate in the post-test administered two months after the first class, it appears that the students did not retain much of the subjects covered in the first class, as measured by the Pret test with an average error rate increase of 5% to almost all the questions. Students demonstrated identical percentages of understanding and memory for two questions alone and for two biological concept questions Q7&Q8, the error rate has reduced when compared to the Pre Test. The increase in correct responses for the question on the respiratory pathway (nose → trachea → bronchi) suggests that students gained a clearer understanding of this fundamental concept after the intervention. The post-test improvement indicates the students were able to recollect the subdivision and the overall divisions in the organ reducing misconceptions and promoting accurate retention, whereas they were not able to recollect the intricate part of the lungs and also its end functions.

Discussion:

The inadequate recollection rates underscore a constraint of conventional lecture-based methodologies, especially regarding abstract biological processes like respiration. Due to the non-observable nature of structures such as alveoli, bronchi and capillaries, students may struggle to mentally image and remember their functions when instructed solely through text or vocal explanations. The absence of multimodal interaction in conventional education certainly hindered profound cognitive processing, resulting in inadequate recall.

Traditional classes may facilitate short-term recognition but may not improve long-term retention and conceptual understanding. This suggests that although conventional instruction may establish a basis, it may be inadequate for fostering robust retention of intricate anatomical and physiological material among school children.

4.6.7 Chi-square Test: Gender-wise Distribution of Pre Test Chalk & Board Responses

HYPOTHESIS 5:

Null Hypothesis H_0 : There is no significant association between gender and Pre Test scores of chalk & board, as tested by the Chi-square test.

Table 4.11 Gender-wise Distribution of Pre Test Chalk & board Student Responses with Chi-square Analysis

Pre Test - Chalk & board	Gender					
					Chi-square Value	P Value
	Male		Female			
	Yes	No	Yes	No		
Q1	34	87	24	55	0.121	0.728
Q2	35	86	17	62	1.363	0.243
Q3	43	78	60	19	2.948	0.086
Q4	28	93	24	55	1.302	0.254
Q5	27	94	23	56	1.179	0.278
Q6	42	79	24	55	0.405	0.524
Q7	87	34	57	22	0.001	0.969
Q8	29	92	31	48	5.309	0.021
Q9	101	20	57	22	3.691	0.055
Q10	44	77	32	47	0.348	0.555

A series of chi-square tests for independence were performed to investigate the relationship between gender and student responses across ten questions given to the Conventional

method – Chalk & board students. The results indicated that for the majority of answers there was no significant correlation between gender and replies (all P value being > .05). Nonsignificant results were observed for Q1 $\chi^2 = 0.12$, $p = .728$; Q2, $\chi^2 = 1.36$, $p = .243$; Q3, $\chi^2 = 2.95$, $p = .086$; Q4, $\chi^2 = 1.30$, $p = .254$; Q5, $\chi^2 = 1.18$, $p = .278$; Q6, $\chi^2 = 0.41$, $p = .524$; Q7, $\chi^2 = 0.00$, $p = .969$; and Q10, $\chi^2 = 0.35$, $p = .555$. A notable correlation was identified for Q8, $\chi^2 = 5.31$, $p = .021$, suggesting a disparity in responses between male and female students for this question “Bronchus divides into bronchioles and ends in options given being a) alveoli b) capillaries. For Q9, $\chi^2 = 3.69$, $p = .055$, neared significance but did not attain the customary threshold. The data demonstrate that both male and female students exhibited an equivalent comprehension for almost all the questions, implying gender did not affect students' responses to questions indicating that understanding of this fundamental biological concept is relatively consistent across genders in the sample. *Overall, these findings indicate that gender was predominantly irrelevant to students' responses*, with a p value greater than 0.05 almost all the question **accept the null hypothesis**, except for one question Q8 where the Chi-square analysis indicated a statistically significant correlation between gender and responses to the inquiry signifies that male and female students had disparities in their comprehension of this idea.

This gender-based disparity indicates that understanding of respiratory system structures may differ between male and female pupils. Potential causes may encompass variations in previous exposure to biology, levels of classroom involvement, or self-assurance in responding to science-related enquiries. These findings underscore the necessity for educators to deliver focused reinforcement of fundamental anatomical ideas, such as the alveoli's function as the lungs' operational unit, while simultaneously rectifying misconceptions.

4.6.8 Chi-square Test: Gender-wise Distribution of Pre Test VR Responses

HYPOTHESIS 6:

Null Hypothesis H_0 :	There is no significant difference between male and female students with regard to experimental VR Pre Test scores pertaining to understanding level
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Table 4.12 Chi-square Test: Gender-wise Distribution of Pre Test VR Responses

Pre Test VR- Experimental Method	Gender				Chi-square Value	P Value
	Male		Female			
	Yes	No	Yes	No		
Q1	92	29	54	25	1.43	0.232
Q2	38	83	28	51	0.352	0.553
Q3	65	56	41	38	0.064	0.801
Q4	69	52	47	32	0.12	0.729
Q5	37	84	19	60	1.01	0.315
Q6	72	49	36	43	3.736	0.053
Q7	93	28	61	18	0.003	0.953
Q8	46	75	30	49	0.000	0.995
Q9	103	18	59	20	3.385	0.066
Q10	31	90	23	56	0.296	0.586

Chi-square tests for independence were performed to investigate the relationship between gender and student responses across ten questions given to the VR students, these are the same questions that were given to the conventional learning students. The results indicated that for most answers there was no significant correlation between genders since all P value being $> .05$. Nonsignificant results were observed for Q1 to Q8 & Q10, suggesting no difference in responses between male and female students and the *null hypothesis is accepted*. For Q9 alone alveoli are surrounded by capillaries $\chi^2 = 3.69$, $p = .053$, neared significance but did not attain the customary threshold. The data demonstrate that both male and female students exhibited an equivalent comprehension for almost all the questions, implying gender did not affect students' responses to questions when learnt through VR indicating that understanding of the fundamental biological concept through Virtual reality is relatively consistent across genders in the sample. Male and female students exhibited similar levels of recall and comprehension, suggesting that VR-based learning environments may offer an egalitarian foundation for science instruction. Virtual reality (VR) depicts the respiratory system in a three-dimensional, realistic and immersive format, facilitating a comprehensive conceptual understanding for all learners, irrespective of gender. Additionally, VR provides multisensory learning experiences—visual,

spatial and interactive—that reduce cognitive obstacles often associated with gender disparities in conventional educational settings.

The lack of gender disparities is promising, suggesting that VR can serve as an inclusive educational instrument for elucidating intricate biological systems. This advocates for the utilization of immersive technology to facilitate equitable learning opportunities, guaranteeing that comprehension of fundamental topics, such as the respiratory system, is uniform across varied student demographics.

The above findings align Kolb’s Experiential Learning Theory (Kolb, 1984) and contemporary research (Chen et al., 2024; Gummelt, 2025), emphasises that experiential learning via immersive technologies, such as VR and AR, promotes active experimentation and tangible experiences, resulting in enhanced understanding of concepts. These findings corroborate the previous studies indicating that experiential learning through interactive and immersive environments improves student engagement, understanding and application of knowledge (Chen, 2025; Kim, 2023).

4.7 Post Test Analysis

4.7.1 Tabulated Data & Analysis of Post Test chalk & board and Post Test VR

Pre Test of Chalk & Board and Pre Test of VR scores are analyzed to find the retention level of the students with regard to the subject respiratory system (objective 2: To investigate the influence of virtual reality on students’, knowledge retention and cognitive abilities)

Table 4.13 Student's Post Test Achievement Percentage %

Questions	PostTest - Chalk & Board <i>Correct answer</i>	Post Test- VR <i>Correct answer</i>
Q1. Haemoglobin in the blood combines with oxygen to form oxyhaemoglobin	23%	78%
Q2. Carbon-di-oxide in the blood, which is released by the tissues, reaches the alveoli through diffusion method	23%	29%
Q3. Carbon-di-oxide from the blood reaches the alveoli and goes out from the body through the nasal passage.	30%	55%
Q4. The alveoli help in the exchange of oxygen and carbon-di-oxide	19%	60%
Q5. Lungs is is organ found in the thoracic cavity	24%	32%
Q6. The air that we breathe through the nose goes first into which part of the lungs. Trachea.	28%	70%
Q7. Trachea divides into two bronchi	76%	85%
Q8. The bronchus again divides into several bronchioles and finally ends in alveoli	23%	33%
Q9. The alveoli is surrounded by blood vessels - capillaries	79%	86%
Q10. The oxygen in the air goes till the alveoli and from there through diffusion reaches the capillaries	38%	20%

To determine the extent to which long-term knowledge is retained, two months following the first set of lectures, the same collection of questions was used again in the form of a post-test. The virtual reality (VR) group and the chalk and board group both took part in the event. The responses were graded according to the same methodology, with a score of 1 for each correct answer and 0 for each incorrect answer. The results of the examination of the scores indicated that, as time passed, the virtual reality (VR) group was able to retain more information than the traditional group. This implies that virtual reality (VR) not only improves initial comprehension, but it also promotes the cognitive memory of difficult biological concepts. These findings shows that VR enhance both short-term learning and long-term memory in the context of science education. This improvement was particularly noticeable in questions that assessed their understanding of spatial and structural concepts. Nevertheless, several abstract ideas shown only a limited amount of progress. With the use of virtual reality (VR), the study shows that science education has the potential to be transformed by increasing student engagement and improving their understanding of the material.

4.7.2 T Test - Post Test of Chalk & Board Vs Post Test of VR

HYPOTHESIS 7

Null Hypothesis H_0 : There is no significant difference between the chalk & board students and VR students with respect to the retention level.

Table 4.14 T test - Post Test Of Chalk & Board Vs Post Test of VR

Method	Mean	SD	T value	P Value
Chalk and board	3.55	1.403	10.580	<0.001
Virtual Reality	5.45	2.109		

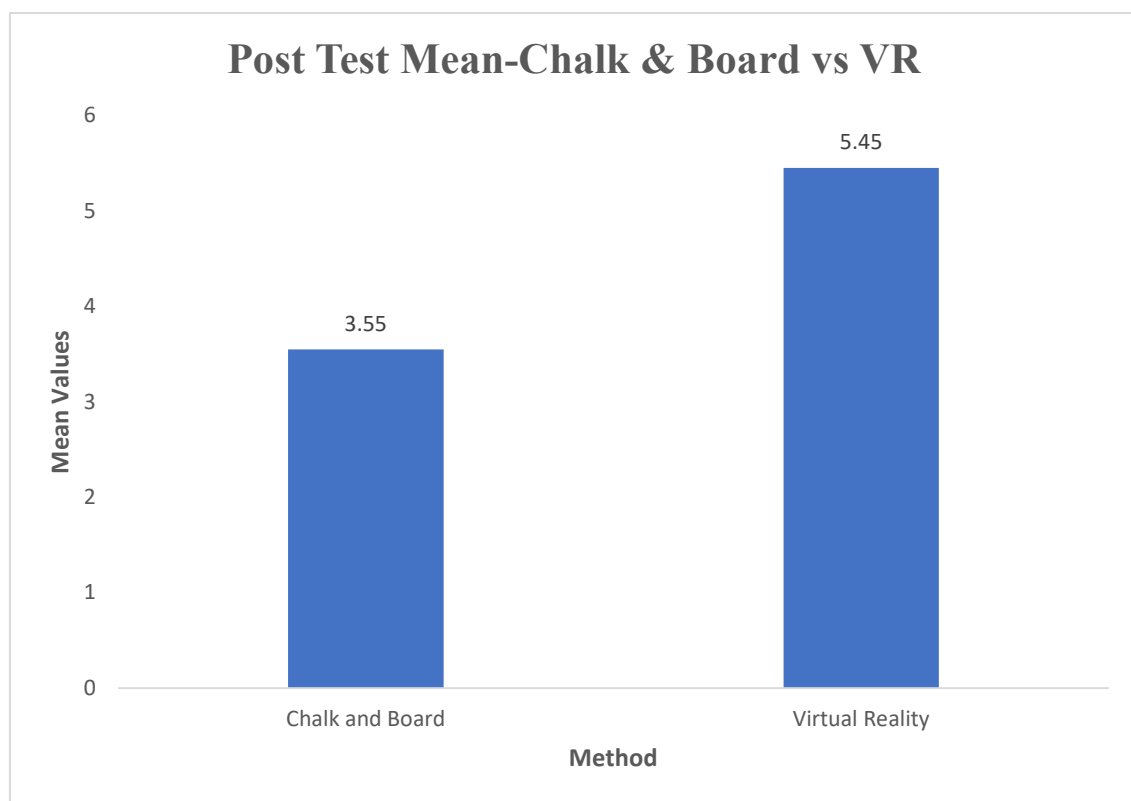


Fig. 4.38 Bar diagram representation of MEAN value of Post Test chalk & board vs Post Test VR

This research objective aims to investigate the differences in retention level among middle school students when taught the respiratory system using traditional chalk-and-board instruction versus Virtual Reality (VR)-based learning. A structured questionnaire comprising

ten concept-based questions related to the respiratory system which was used in the Pre Test was utilized as a tool for assessment. The study involved the same set of students who attended the chalk & board and VR in the Pre Test. Following their respective instructional sessions, both groups were administered the same questionnaire as a pre-test to evaluate immediate comprehension. To assess long-term retention, the same set of questions was re-administered to both groups after a duration of two months. This post-test aimed to measure the retention recall of the content taught through the two instructional approaches. The responses from both the groups were analyzed to determine the comparative effectiveness of VR-based instruction in enhancing memory retention.

Based on the analysis results, *null hypothesis has been rejected at a significance level of 1 %*, the p value being less than 0.001 indicating that the students who learnt through VR were able to recollect the subject better when compared to the students who learnt the subject through conventional methods. The Post Test was taken after a duration of 2 months, almost 60 days, the students who learnt through VR showed a very positive sign of remembering most of the important intricate process.

Table 4.15 Correct Responses - Post Test scores of Chalk & Board vs Post test VR

Q.Nos.	Post Test chalk & board	Female - correct answers	Post Test VR	
	Male -correct answers		Male-correct answers	Female-correct answers
Q1	22	24	93	63
Q2	25	21	38	20
Q3	37	23	60	50
Q4	26	12	71	49
Q5	31	17	40	24
Q6	30	26	82	58
Q7	93	59	107	63
Q8	21	25	32	34
Q9	101	57	106	66
Q10	48	28	20	20

Question wise Analysis for Post Test chalk & board vs Post Test VR

The comparison of post-test chalk & board and post-test VR responses across ten conceptual questions on the respiratory system reveals a significant improvement in knowledge retention among students on the use of Virtual Reality (VR) instruction. The data clearly indicates that

students exposed to VR demonstrated greater comprehension and retention of the subject matter than those taught through conventional chalk-and-board methods.

In the first question regarding the formation of oxyhemoglobin, the post-test correct response rate of chalk & board was 23%, while the scores of VR learning showed a drastic increased value of 78% with a 55 % increased correct responses. This indicates that the immersive visualization provided by VR helped students better understand abstract physiological concepts.

In contrast, Question 2, which asked about the method of CO₂ transport, saw only a marginal increase from 23% to 29%. This suggests that while VR is effective for visual and structural learning, additional explanation may be required for abstract or biochemical processes.

Question 3, regarding the pathway of CO₂ exiting the body, saw an increase in correct responses (30% to 55%), indicating that VR helps in the clear exhalation passage of gases

Similarly, in Question 4 on the role of alveoli in gas exchange, correct answers rose from 19% to 60 %, suggesting maximum change in conceptual clarity when VR was used to demonstrate lung function.

Question 5 (lungs' location in the thoracic cavity) showed a minimal positive change (24% to 32%), indicating that voice overs and terminologies have to be emphasized in the VR module.

Question 6 (airflow through the trachea) The anatomical routes and processes shown a notable increase in responses, rising from 28% of correct responses in chalk & board when compared to the 70% increased response in VR. This indicates that VR is advantageous for maintaining airflow through the movement of air molecules in the trachea.

Question 7 (trachea division) also showed notable gains in correct responses—76% to 85% %, These findings suggest that VR enhanced spatial understanding and structure-function relationships, which are often challenging to grasp through traditional teaching.

Question 8 (end part of bronchi) showed 23 % to 33 % shows an increase in retention level in identifying the end part as alveoli, implying VR helps in recollecting the structural parts of the organs.

Question 9, about alveolar surroundings, showed already high pre-test scores 79%, with a gain to 86 % in post-test. The application of Virtual Reality (VR) has contributed to this

enhancement, since the immersive 3D depiction allowed students to examine the anatomical arrangement of alveoli and the surrounding capillary network.

Question 10 surprisingly saw a drop in performance from 38% correct in the pre-test to 20% in the post-test. This decline could indicate possible misconceptions introduced during VR instruction or insufficient reinforcement of the diffusion concept during the immersive experience.

All things considered, these deductions lend credence to the idea that virtual reality greatly improves comprehension and retention of spatially dependent and aesthetically complicated biological material, especially that which pertains to physiology and anatomy. Questions concerning the anatomy and physiology of the respiratory system yielded the highest improvements giving a positive hope that students were able to recollect even after two what they learn through VR. Virtual reality (VR) might require further instructor teaching or interactive discussion in domains necessitating more complex conceptual or physiological thinking.

This research highlights the need of hybrid learning strategies which is helping more in understanding and recollecting the subjects that integrate the benefits of virtual reality visualization with the breadth and depth of traditional classroom instruction. To make sure that students learn the right stuff in science across all levels of cognition, future instructional designs should make sure that virtual reality content is closely tied to curriculum objectives.

4.7.3 Chi-square Test: Post Test Chalk & board vs Gender

HYPOTHESIS 10:

Null Hypothesis H_0 : There is no significant difference between male and female students with regard to the retention level of the students when taught through chalk & board conventional method.

Table 4.16 Chi-square Test – Post Test Chalk & Board vs Gender

Post Test Chalk & Board	Gender				Chi Square Value	P Value
	Male		Female			
	Yes	No	Yes	No		
Q1	22	99	24	55	4.015	0.045
Q2	25	96	21	62	0.946	0.331
Q3	37	84	23	56	0.049	0.825
Q4	26	95	12	67	1.232	0.267
Q5	31	90	17	62	0.441	0.507
Q6	30	91	26	53	1.562	0.211
Q7	93	28	59	20	0.124	0.725
Q8	21	100	25	54	5.511	0.019
Q9	101	20	57	22	3.691	0.055
Q10	48	73	28	51	0.362	0.547

Chi-square tests for independence were performed to investigate the relationship between gender and student responses across the same ten questions which was given to the Conventional method – Chalk & board to find the retention level, which was taken from the students after 2 months from the initial class. The results indicated that for the majority of answers there was no significant correlation between gender and replies (all P value being > .05). Nonsignificant results were observed for Q2, $\chi^2 = 0.946$, $p = .331$; Q3, $\chi^2 = 0.049$, $p = .825$; Q4, $\chi^2 = 1.232$, $p = .267$; Q5, $\chi^2 = 0.441$, $p = .507$; Q6, $\chi^2 = 1.562$, $p = .211$; Q7, $\chi^2 = 0.124$, $p = .725$, p value being more than 0.05 *accept the null hypothesis*. A notable correlation was identified for Q1 $\chi^2 = 4.015$, $p = 0.04$; Q8, $\chi^2 = 5.511$, $p = .019$, suggesting a disparity in responses between male and female students for this question and for Q9, $\chi^2 = 3.691$, $p = .055$ and Q10, $\chi^2 = 0.362$, $p = .0547$ neared significance but did not attain the customary threshold. The data demonstrate that both male and female students exhibited an equivalent retention level for six questions out of 10 and neared significance for two questions and a significant difference in the retention level among male and female students for Q1, $\chi^2 = 4.015$, $p = 0.045$. For Q1 alone “Hemoglobin combines with oxygen to form oxyhemoglobin” male and female students differed in their ability to recall and write the correct answer where female students were able to recollect better. The findings suggest that gender affected pupils' capacity to remember the

accurate understanding that hemoglobin associates with oxygen to create oxyhemoglobin. A significant majority of female students answered correctly, but the other group exhibited considerably lower recall accuracy. This indicates that the memory and recall of biological terminology and processes may differ between genders and the findings underscore the necessity of reinforcing essential biochemical concepts, such as oxyhemoglobin production, using active learning methodologies, visual aids and repeated contextual practice, ensuring that both male and female students can retain and retrieve the concept with similar proficiency.

4.7.4 Gender vs Post Test VR Scores

HYPOTHESIS 11:

Null Hypothesis H_0 : There is no significant difference between male and female students with regard to the retention level when respiratory system is taught through VR

Table 4.17 Gender vs Post Test VR

Post Test VR	Gender				Chi Square Value	P Value
	Male		Female			
	Yes	No	Yes	No		
Q1	93	28	63	16	0.232	0.63
Q2	38	83	20	59	0.86	0.354
Q3	60	61	50	29	3.627	0.057
Q4	71	50	49	30	0.223	0.637
Q5	40	81	24	55	0.158	0.691
Q6	82	39	58	21	0.726	0.394
Q7	107	14	63	16	2.826	0.093
Q8	32	89	34	45	5.951	0.015
Q9	106	15	66	13	0.654	0.419
Q10	20	101	20	59	2.307	0.129

For most of the respiratory system questions, there was no discernible correlation between gender and answers according to a chi-square test of independence with a p value >0.05 and hence we *accept the null hypothesis*. Comparable performance between the sexes showed that retention rates were often high. Virtual reality-based learning facilitates equitable recall of complicated biological concepts, as demonstrated by students' uniform performance across nearly all questions, regardless of gender. The question "The end part of the lungs is alveoli or capillaries" showed a significant difference, $X^2 = 5.951$; $p = .015$, indicating that there was a gender difference in the answers to this particular question alone possibly due to the difference between alveoli and capillaries is conceptually nuanced, which could explain the discrepancy. The alveoli are the end sacs of the lungs and the capillaries are the blood vessels that surround them; their structures and functions are quite similar. Some students may have confused the two, leading to a range of answers, because their comprehension was incomplete. This one discrepancy may be due to item-specific difficulty rather than a general gender divide in learning, since most questions did not reveal any differences. Thus, although it seems that VR learning promotes consistent memory across genders, the one exception shows that there has to be more emphasis on the conceptual intricacies like differentiating between capillaries and alveoli still more clearly and voice over related to this differentiation can help the students to avoid the confusion.

The overall results pertaining to all the Pre Test of Chalk & Board and Post Test of both chalk & board and VR questions emphasize that Q8 – "the end part of the respiratory system is alveoli or capillaries" gained a disparity among gender in both the conventional and VR method with regard to the retention level in VR and both understanding and retention level in chalk & board, the reason could be the conceptual overlap, since the alveoli is surrounded by capillaries, the students would have thought that the end is capillaries since the two structures are functionally interlinked, confusion is common and one gender may have been more prone to this mix-up also students confused the terminal structure of the respiratory system (alveoli) with the surrounding blood vessels (capillaries). This represents largely a conceptual clarity deficit, as the distinction between respiratory and circulatory systems was not well defined. A secondary element could be observational clarity, as the visual proximity of alveoli and capillaries in diagrams or animations may have added to the confusion. Experimental studies report that female students show relatively higher retention when learning via animations (Heo, M, 2020).

4.7.5 Paired Sample T test – Pre Test VR vs Post Test VR

HYPOTHESIS 8:

Null Hypothesis H_0 : There is no significant difference between the Pre Test and Post Test scores pertaining to understanding & retention level when learnt through VR

Table 4.18 Paired Sample T test – Pre Test of VR vs Post Test of VR

Paired Samples Statistics

Test Types		Mean	SD	t value	P value
VR	Pre Test	5.05	2.043	2.883	0.004**
	Post Test	5.45	2.109		

Note : ** denotes significance level at 1 %

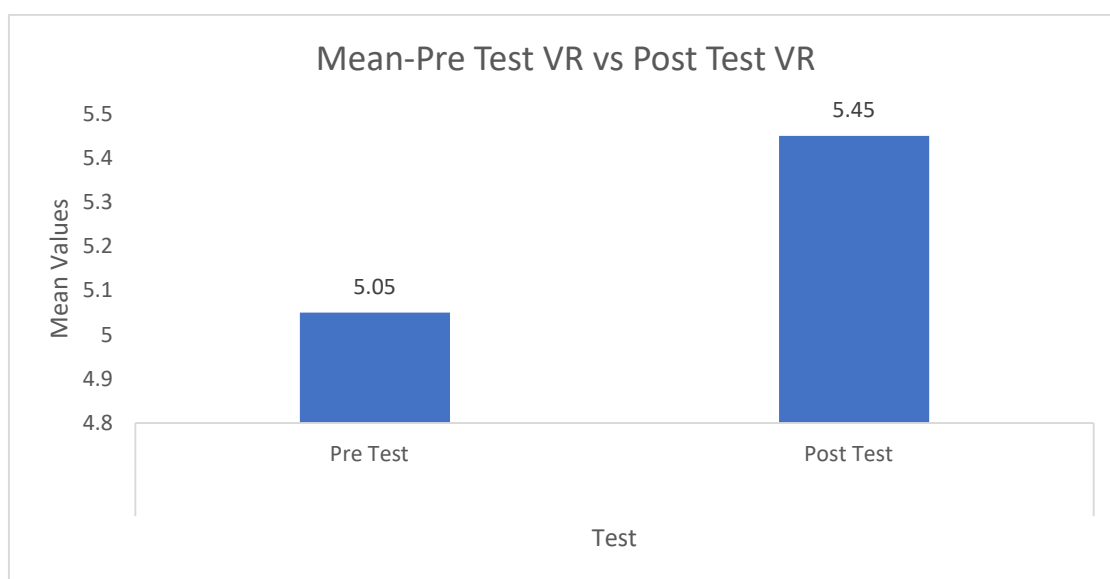


Fig. 4.39 Bar diagram representation of MEAN value of Pre Test vs Post Test of VR

Pretest was conducted to the VR students immediately after they saw the VR content by wearing the VR kit and the structured questionnaire which was given to the chalk & board students were given to the VR based learning students, immediately after they learnt the subject respiratory system in the googles and the marks have been evaluated. To assess long-term retention, the same set of questions was re-administered to the same group of students after two months. The responses from pre-test and post-test were analyzed to determine the comparative

effectiveness of VR method of learning in understanding and retention level. Based on the analysis, *the null hypothesis is rejected at a significance level of 1 %*, at a p value of 0.004, which indicates that there is a significant difference in the both the understanding and the retention level of VR students, the retention level has increased meaning that the students were able to recollect the subject even after a period of two month when compared to the results of the pretest taken immediately after the session. Animations and colors that have been used in VR could be an interesting and remembering factor to recollect better. Mean value of Pre Test VR being 5.05 and mean value of pos test VR being 5.45, the increased mean value of Post Test reveals that the student retention level of VR students is more.

4.7.6 Error % - Post Test Chalk & Board vs VR

Table 4.19 Error % Between the Post Test Chalk & Board vs VR

Q. No	Post-Test Chalk & Board	Post-Test VR
	Wrong (%)	wrong (%)
Q1	77%	22%
Q2	77%	71%
Q3	70%	45%
Q4	81%	40%
Q5	76%	68%
Q6	72%	30%
Q7	24%	15%
Q8	77%	67%
Q9	21%	14%
Q10	62%	80%

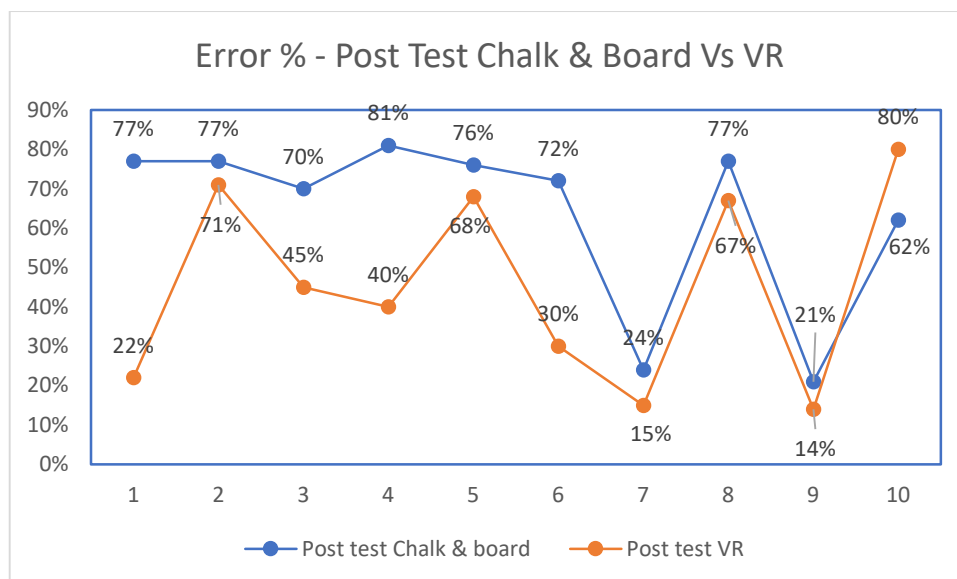


Fig. 4.40 Error % - Post Test Chalk & Board Vs VR

The proportion of incorrect responses provided by students from the two groups—conventional group (chalk & board) & experimental group (VR)—was analysed. In the conventional class group, the proportion of incorrect responses continually remained elevated across most questions (e.g., 77%, 81%, 76%, 72%, 80%), signifying challenges in understanding and retaining concepts. The VR group had a significant decrease in incorrect responses, demonstrating markedly lower percentages for the identical questions (e.g., 22%, 45%, 40%, 30%, 15%, 14%).

The VR groups error rate was significantly lower than that of the chalk & board group, indicating that VR classes enhanced conceptual clarity and reduced misconceptions regarding the respiratory system.

Discussion:

The comparison between traditional and animation-based learning demonstrates a notable disparity in the precision of students' responses. Students who participated in the standard classroom sessions displayed a significant proportion of incorrect responses, indicating difficulties in memorizing and applying information about the respiratory system. This may result from the abstract nature of the subject, wherein text-based or lecture-only methodologies offer insufficient visualization of internal processes such as gas exchange, alveolar architecture and capillary functions.

Conversely, students engaged with VR learning provided far less incorrect responses, underscoring the efficacy of visual and interactive methodologies in enhancing precise comprehension. The animated depiction of respiratory anatomy likely assisted learners in distinguishing between analogous ideas (e.g., alveoli versus capillaries), thereby minimizing misconceptions. The minimal error rate (as low as 14–15% in certain items) unequivocally illustrates enhanced comprehension, retention and clarity facilitated by animation.

These data substantiate the notion that VR learning enhances post-test scores and markedly diminishes conceptual errors relative to conventional techniques. This suggests that these methods are more efficacious in enhancing both retention and conceptual precision in children.

The findings suggest that integrating VR into science classrooms can improve conceptual clarity and long-term retention. Educators can use VR as a supplementary tool for teaching complex biological systems. However, VR should be blended with direct instruction for topics that require abstract reasoning. Curriculum designers must align VR content closely with learning objectives to ensure pedagogical effectiveness. Schools and policymakers should consider investing in immersive technologies for core science topics. Overall, VR has the capacity to make learning more memorable, interactive and student-centered.

The above results are consistent with Cognitive Load Theory (Sweller, (1988) and recent research by Kim, S. S. (2025), demonstrating that groups undergoing transitions prior to learning demonstrated enhanced memory recall and engagement, underscoring the efficacy of strategically positioned VR transition spaces as cognitive facilitators. These findings corroborate previous studies indicating augmented reality interventions enhanced students' retelling performance, demonstrating a beneficial effect on memory recall. (Şimşek, B., et al. 2025)

4.8 Analysis of VR's impact on Cognitive Load

Survey questions were analyzed to find the impact of VR on Cognitive Load (Objective 2: To investigate the influence of virtual reality on students' knowledge retention and cognitive load)

This objective explores how animations and colors in VR influence students' cognitive load. Animations help simplify complex biological processes, increase attention span and enhance memory retention. Colors contribute by stimulating emotional engagement, improving concentration and aiding recall. To assess this, a structured questionnaire with multiple-choice

questions was administered to students. They were asked to select the most appropriate answers based on their experience with VR lessons. The responses provided insight into how visual elements impacted their understanding. The results supported the idea that vibrant visuals positively influence cognitive learning outcomes. This data was used to evaluate the effectiveness of VR in enhancing cognitive performance.

4.8.1 T test – Cognitive Load with respect to Gender

HYPOTHESIS 12:

Null Hypothesis H_0 : There is no significant difference between male and female students' responses with regard to the Cognitive load when subject respiratory system learnt through VR

Table 4.20 – T test – Cognitive Load with respect to Gender

Group Statistics					
	Gender	Mean	SD	t value	P value
Cognitive Load	Male	8.55	1.176	0.276	0.783
	Female	8.59	1.335		

Cognitive load theory posits that human working memory has finite capacity and if we are given too much information at once or content is given in a complex way, it increases superfluous cognitive load, making it tougher for learners to process, retain and later recall the material. Animations free up working memory resources by reducing unnecessary load, which enables students to concentrate on the intrinsic load—the important information. The mental work required to create long-term memory structures is known as relevant cognitive load and this supports it. Because knowledge was processed more efficiently and stored in memory more successfully, students not only comprehend material better but also recall it more readily. Since VR uses animated content, the cognitive load was tested among the VR students. To measure the cognitive load a set of 10 questions which is different from the one used in Pre Test and Post Test has been used. The questionnaire is dichotomous questions where questions related to the lungs and key factors like animations or colors that helped them to recollect the subject easily have been taken in consideration; to find out which factor helped them to recollect the

subject easily without much cognitive Load. Most students gave affirmative answers to the dichotomous (yes/no) items, as indicated by the mean score above 8.5, which suggests substantial agreement and a positive attitude towards the intervention. The analysis reveals that mean value = 8.55 for male and mean value = 8.59 for female and a p value of 0.783 which is greater than 0.05 indicates that both the genders experienced a similar level of cognitive load and *we accept the null hypothesis* stating that there is no significant difference between genders regarding cognitive load.

Table 4.21 Cognitive Load -Gender-wise Responses

Cognitive Load	Male (Yes)	Female (Yes)	Total Yes	Male (No)	Female (No)	Total No	Total Responses
C1	36	12	48	90	62	152	200
C2	102	68	170	24	6	30	200
C3	118	64	182	8	10	18	200
C4	32	22	54	94	52	146	200
C5	126	74	200	0	0	0	200
C6	126	74	200	0	0	0	200
C7	126	74	200	0	0	0	200
C8	18	24	42	108	50	158	200
C9	126	74	200	0	0	0	200
C10	126	74	200	0	0	0	200

The data gathered from 200 students (126 men and 74 females) about their knowledge and retention of respiratory system components, notably via Virtual Reality (VR)-based learning, provides substantial insights into conceptual understanding across genders. Initially, the inquiry “The right lung has 2 lobes” garnered correct responses (No being the correct answer) from 152 students (90 males and 62 females), whereas 48 students answered wrong marking Yes as the correct answer. This signifies a profound comprehension of the lung structure and its lobes. One hundred seventy students (102 men, 68 females) accurately identified that the left lung comprises two lobes, indicating a greater understanding of this anatomical detail. The disparity in performance between the right and left lung structures may be attributed to the left lung's distinctive characteristic (cardiac notch), rendering it more recognizable in visual representations such as virtual reality. The third question concerning the bifurcation of bronchi into bronchioles had 182 accurate answers, indicating a robust understanding among both genders (118 males and 64 females). This indicates that dynamic representations in VR effectively reinforced the sequential anatomical flow.

Nonetheless, ambiguity reemerges with the inquiry, “The terminal section of the lungs is the bronchioles.” 146 respondents answered correctly (No is the correct answer), whilst 54 answered incorrectly (Yes), indicating a clear understanding of lung shape. Notably, all 200 students answered correctly to the question, “The end part of the lungs is alveoli,” with no gender differences seen. This suggests that students possess a strong comprehension of alveoli, frequently highlighted in both written and visual forms, potentially owing to the vivid portrayal of gas exchange in virtual reality settings.

Moreover, inquiries regarding the recollection of VR sceneries, including air passage from the trachea to the bronchus, alveoli encircled by capillaries and the depiction of red-hued oxyhaemoglobin and purple-hued red blood cells, yielded 100% accuracy in responses from both genders. This suggests that immersive VR graphics were exceptionally effective in embedding such sequences in students’ memory, 158 students responded correctly by answering No to the question. “I remember Air from alveoli get transported to capillaries and the carbon dioxide alone will get converted as oxyhaemoglobin” which confirms that students were able to understand the exchange of gases. The studies indicate that VR-based education significantly improves visual memory and sequence comprehension, especially in processes like as gas exchange and anatomical circuits. End part of the lungs being alveoli or the capillary needs reinforcement via instructor-led elucidation, interactive question-and-answer sessions and integrated illustrations. Males somewhat surpass females in total accurate responses, with the exception of specific higher-order questions. This slight variation might be ascribed to differing learning styles rather than cognitive capacity, highlighting the necessity for flexible and inclusive teaching methodologies.

Discussion:

The data gathered from students who participated in the VR-based course on the respiratory system provides significant insights into their comprehension and memory of essential biological concepts. A majority of students (78.5%) accurately recognized that the right lung does not include two lobes, demonstrating moderate understanding of lung anatomy, while an even larger percentage (86%) properly acknowledged that the left lung has two lobes, indicating superior retention of this information. A robust comprehension of bronchial anatomy was noted, with 91.5% correctly indicating that the bronchi bifurcate into bronchioles. Nonetheless, when inquired about the terminal portion of the lungs, confusion arose—merely

63% accurately identified alveoli as the terminal structure, whereas 37% conflated it with capillaries, underscoring a deficiency in differentiating microscopic lung anatomy.

Notably, visualization seems to have markedly improved learning. Nearly 99.5% of students recalled observing air passage from the trachea to the bronchus, as well as the alveoli being encircled by capillaries. These notions, adeptly depicted in virtual reality, appear to have made a significant impact. The depiction of oxygen transport was positively acknowledged—98.5% recalled red-hued oxyhaemoglobin and purple-hued red blood cells interacting with oxygen, underscoring the efficacy of color-coded visual metaphors in virtual reality. The results indicates that VR-based teaching substantially enhances memory retention and visual learning, particularly for structural and process-oriented material. Nonetheless, it emphasizes the necessity for meticulous instructional framing to avert scientific mistakes. The integration of immersive graphics and supportive instruction may successfully address these learning deficiencies. Virtual reality has demonstrated significant efficacy in improving engagement and retention, although it should be complemented by formative testing to elucidate misunderstandings.

The results from this VR-based evaluation demonstrate that immersive technology can markedly improve pupils' comprehension and retention of intricate biological processes. Most students accurately recognized anatomical structures including lung lobes, airways and alveoli, demonstrating that virtual reality successfully enhances visual-spatial learning. The 99% recall rate for dynamic visual elements—such as airflow in the respiratory system and the visual distinction of oxygenated blood—illustrates the influence of color-coded and animated representations on knowledge retention. However, the misconception held by 21% of students regarding the transformation of carbon dioxide into oxyhemoglobin highlights a limitation. This suggests that while VR enhances recall, it may not fully convey conceptual accuracy unless complemented by guided explanation and reflective discussion. The misunderstanding points to the need for teachers to play an active role in debriefing VR sessions, ensuring that students not only see but also correctly interpret what they experience. This discussion highlights that VR should be seen as a pedagogical enhancer rather than a standalone teaching tool. It is most effective when integrated with traditional teaching methods, assessments and corrective feedback. With meticulous design and pedagogical assistance, virtual reality has the capacity to transform science education by rendering abstract concepts concrete, engaging and memorable.

Our results align with the Cognitive Load Theory (Sweller, 1988) and recent research (Larmuseau et al., 2025; Smith, 2025), demonstrated that VR and animations reduce extraneous cognitive strain and facilitate enhanced learning. These findings support previous studies indicating that animations and immersive technology improve memory retention and engagement (Ploetzner et al., 2024).

4.8.2 Chi-square Test: Gender vs Cognitive Load

HYPOTHESIS 13:

Hypothesis H₀ : There is no significant association between gender and cognitive load as tested by the Chi-square test.

Table 4.22 Gender vs Cognitive Load

Cognitive load	Male		Female		Chi Square Value	P Value
	Yes	No	Yes	No		
C1	91	30	66	13	1.969	0.161
C2	101	20	71	8	1.627	0.202
C3	108	13	75	4	1.983	0.159
C4	72	49	54	25	1.606	0.205
C5	120	1	79	0	0.656	0.418
C6	119	2	78	1	0.048	0.826
C7	121	0	78	1	1.539	0.215
C8	106	15	57	22	7.568	0.006
C9	117	4	76	3	0.034	0.853
C10	117	4	75	4	0.384	0.535

The Chi-square test was performed to assess the significant association between students' gender and their replies to the cognitive load questionnaire (10 yes/no items) following instruction via animation. The findings revealed no statistically significant difference between male and female pupils ($p > 0.05$) and we *accept the null hypothesis except for C8*. This

indicates that the cognitive strain encountered during animation-based learning was similar between genders. The lack of substantial gender disparities indicates that learning via animation equally alleviated cognitive burden for both male and female students. This finding indicates that the advantages of animation-based instructions such as enhanced visualization, dynamic depiction of abstract concepts and the application of color to emphasize structures—benefited learners uniformly, irrespective of gender. Cognitive Load Theory (Paas, Renkl & Sweller, 2003; Yue et al., 2013; Moreno & Mayer, 2003) posits that well-designed animations—characterized by cohesive visuals, integrated color coding and minimized extraneous elements—can reduce extraneous cognitive load, thereby enabling a greater allocation of working memory resources to germane cognitive load, which facilitates learning, which very well substantiate our findings.

This study suggests that color-coded animations probably reduced confusion and enhanced recall by focusing attention on essential characteristics. The diminished cognitive load experienced by pupils can be ascribed to the animation's effective design, which enhanced learning without requiring extra mental exertion.

4.9 Analysis of VR's impact on Holistic Student Development

Objective 3: To examine the impact of virtual reality-based teaching on Holistic Student Development (student engagement, satisfaction and interest toward learning and learning resilience)

4.9.1 Chi-square Test: Gender vs Holistic Student Development

HYPOTHESIS 14:

Null Hypothesis H_0 : There is no significant difference between male and female students with regard to Holistic Student Development

One Way ANOVA:

Table 4.23 Gender vs Holistic Student Development

Holistic Student Development		Male					Female					Chi square Value	P Value
		Strongly Agree	Agree	Neutral	disagree	strongly disagree	Strongly Agree	Agree	Neutral	disagree	strongly disagree		
Student Engagement	se1	104	17					68	11			0.001	0.98
	se2	89	31	1				53	25	1		0.993	0.609
	se3	84	37					56	23			0.049	0.825
Learning Resilience	LR1	78	43					48	31			0.281	0.596
	LR2	114	7					72	7			694	0.405
	LR3	67	54					47	32			0.331	0.565
	LR4	16	9	15	59	22	6	5	8	32	28	1.539	0.215
Student Satisfaction	ss1	0	15	21	46	39	0	5	13	32	29	2.140	0.544
	ss2	0	1	0	72	48	0	1	0	44	34	0.344	0.842
	ss3	0	2	1	61	57	0	2	1	37	39	0.453	0.929
	ss4	10	54	30	18	9	5	44	21	6	3	4.66	0.324
	ss5	30	65	10	9	7	17	44	11	3	4	2.811	0.59
	ss6				94	62				27	17	0.018	0.894
Learning Interest	LI1	117	4				6	73				1.851	0.174
	LI2	105	16				67	12				0.154	0.695
	LI3	90	31				60	19				0.063	0.802
	LI4	57	14	20	9	21	37	14	11	6	11	1.855	0.762

We *accept the null hypothesis as the p-value exceeds 0.05* for all parameters associated with Holistic Student Development. There is no substantial difference between male and female students for holistic student development. The variables of student involvement, student happiness, overcoming learning difficulties and interest in learning indicate that there is no substantial difference between male and female students. Male students express high agreement over their engagement throughout VR classes, reporting minimal distractions, while female students also concur that they remain engaged throughout the VR sessions. The selection of the Strongly Agree option by male students signifies a higher level of engagement among them. Likewise, male students highly concurred that VR facilitated the overcoming of learning difficulties, while female students expressed agreement as well. Regarding the student satisfaction factor, the students strongly disagreed with the assertion that they experience headaches when learning through VR, feel drowsy during VR lessons and struggle to comprehend material presented via VR. Furthermore, many students concurred that they

require both traditional classroom instruction and VR classes, expressing a preference for VR and a belief that it enhances their understanding. Most pupils expressed significant agreement that they would attend school if classes were conducted in virtual reality. There is no significant difference between male and female students across all parameters, indicating the absence of gender imbalance in Holistic Student Development.

4.9.2 Likert Scale - Student Responses on Holistic Student Development

Table 4.24 Overall Distribution of Student Responses by Agreement Level

Holistic Student Development	Strongly Agree	Agree	neutral	Disagree	Strongly Disagree	Strongly Agree %	Agree %	Total Acceptance %
SE1	104	85	11	0	0	52	42.5	94.5
SE2	89	84	26	1	0	44.5	42	86.5
SE3	84	93	23	0	0	42	46.5	88.5
LR1	78	91	31	0	0	39	45.5	84.5
LR2	114	79	7	0	0	57	39.5	96.5
LR3	67	101	32	0	0	33.5	50.5	84
LR4	22	14	23	91	50	25	45.5	70.5
SS1	68	78	34	20	0	34	39	73
SS2	0	116	0	2	0	41	58	99
SS3	96	98	2	4	0	48	49	97
SS4	15	98	51	24	12	7.5	49	56.5
SS5	47	109	21	12	11	23.5	54.5	78
SS6	79	121	0	0	0	39.5	60.5	100
LI1	123	77	0	0	0	61.5	38.5	100
LI2	172	28	0	0	0	86	14	100
LI3	150	50	0	0	0	75	25	100
LI4	94	28	31	15	32	47	14	61

Student Engagement: (SE)

Items: SE1, SE2, SE3 - SE1: Class taken using VR is interesting to me, SE2: I don't feel bored during VR class, SE3: VR helps to remember the subject, giving a feeling of encouragement

Table 4.25 Student Engagement

Student Engagement	Questions	Strongly Agree %	Agree %	Total Acceptance %
SE1	Classes taken using VR is interesting to me	52%	42.5%	94.5
SE2	I don't feel bored during VR class	44.5%	42%	86.5%
SE3	VR helps to remember the subject giving a feel of encouragement	42%	46.5%	88.5%

SE1: Classes taken using VR is interesting to me

SE1:

A significant majority 52% (104 male ,0 female) students strongly agreed that VR classes were interesting and 42.5% (17 male and 68 female) agreed to it totaling to 94.5 % students in acceptance to the question” Classes taken using VR is interesting to me” There were no negative responses. This shows strong enthusiasm and acceptance of VR in learning environments. The immersive experience likely contributed to sustained attention and increased student motivation.

SE2: Don't feel bored if class is in VR

SE2:

44.5% (89 male) of students strongly agreed that they don't feel bored when they attend class in VR and 42% (31male, 53 female) agreed to it and 0.5 % stood neutral and 0.5 % of the students disagreed. This shows strong enthusiasm and acceptance of VR in learning environments. The immersive experience likely contributed to sustained attention and increased student motivation

SE3: VR helps to remember the subject by giving a feeling of encouragement

SE3:

42% of students strongly agreed that VR classes helped them to remember the subject, since they were able to remember and they felt encouraged to attend the VR classes and 42% agreed. There were no negative responses. The immersive experience likely contributed to retention level which makes the students encouraged.

Table 4.26 Learning Resilience (Overcoming Learning Difficulty)

Learning Resilience	Questions	Strongly Agree %	Agree %	Total Acceptance %
LR1	VR class helps to recollect the shape and parts of lungs easily	39 %	45.5 %	84.5 %
LR2	VR helps me to look closely the lungs in a bigger size; it helps me to remember	57 %	39.5 %	96.5%
LR3	I feel comfortable to see in VR and learn the lesson	33.5%	50.5%	84%
LR4	I find it simple and easy to learn in VR	25%	45.5%	70.5%

LR1:

LR1: VR class helps to recollect the shape and parts of lungs easily

39 % of students strongly agreed that VR helps them to recollect the shape and parts of the lungs easily and 45.5 % agreed to it. Always students tend to forget the parts of the organ. The overall 84.5 % positive response indicates that VR classes are helping students to recollect the subject.

LR2:

LR2: VR helps me to look closely at the lungs in a bigger size, it helps me to remember

57 % of students strongly agreed that VR helps me to look closely the lungs in a bigger size, it helps me to remember and 39.5 % agreed, totaling to 96.5%, indicating that Animation facilitates a more thorough examination of the concepts by students Viewing the organs in a bigger size will help to remember easily and capacity to enlarge and rotate anatomical models enhance the learning experience.

LR3:

LR3: I feel comfortable to see in VR and learn the lesson

33.5% of students strongly agreed VR makes them feel comfortable to learn the subject 50.5 % agreed to it totaling to 84% indicating that VR gives a realistic feel, which reduces ambiguity and makes the students clear in what they are learning, giving a feel of comfortability

LR4:**LR4: I find it simple and easy to learn in VR**

25% of students strongly agreed that learning in virtual reality (VR) is simple and effortless, while 45.5% concurred, indicating that VR, through animated content presented impressively, facilitates ease of learning.

Table 4.27 Student Satisfaction

	Student Satisfaction	SA	A	N	S	SD	Strongly Agree %	Agree %	Total Acceptance %
SS1	I don't get headaches when I attend class in VR (paraphrased and reverse coded)	68	78	34	20	0	34%	39%	73%
SS2	I am able to understand when learnt through VR	0	116	0	2	0	41%	58%	99%
SS3	I don't feel sleepy when learn through VR (paraphrased – reverse coded)	96	98	2	4	0	48%	49%	97%
SS4	I understand better when I am explained on the board using chalk	15	98	51	24	12	7.5%	49%	56.5%
SS5	I need both the teacher's class and VR for better understanding	47	109	21	12	11	23.5%	54.5%	78%
SS6	Attending VR classes leads to knowledge acquisition	79	121	0	0	0	39.5%	60.5%	100%

SA – Strongly Agree; A- Agree; N-Neutral; D-Disagree; SD- Strongly disagree; TA – Total Acceptance

SS1:

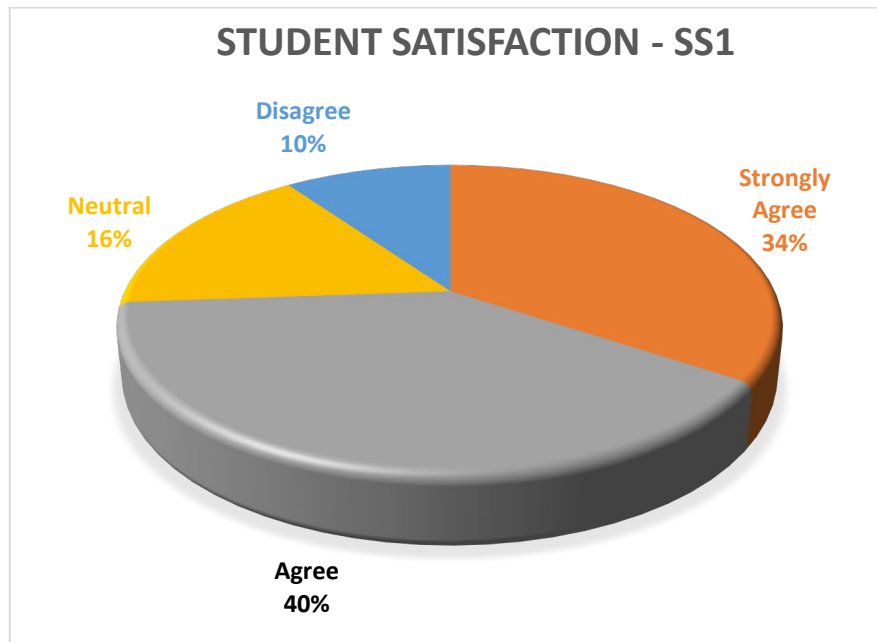


Fig. 4.41 Likert scale rating on not getting headache while attending VR class

SS1: I get headache when I attend class in VR – (the question has been paraphrased as “I don’t get headache when I attend class in VR “for analysis purpose and the values are entered in accordance to the students’ responses -reverse coded)

10 % of the students expressed discomfort and 16 % of the students stayed neutral. A high percentage (40% agree, 34% strongly agree) reported that they didn’t experience headaches during VR sessions. 10 % strain also could be minimized by giving regular breaks which could minimize the discomfort.

SS2:

SS2: I am able to understand when learnt through VR - – (the question has been paraphrased from “I am not able to understand when VR “for analysis purpose and the values are entered in accordance to the students’ responses – reverse coded)

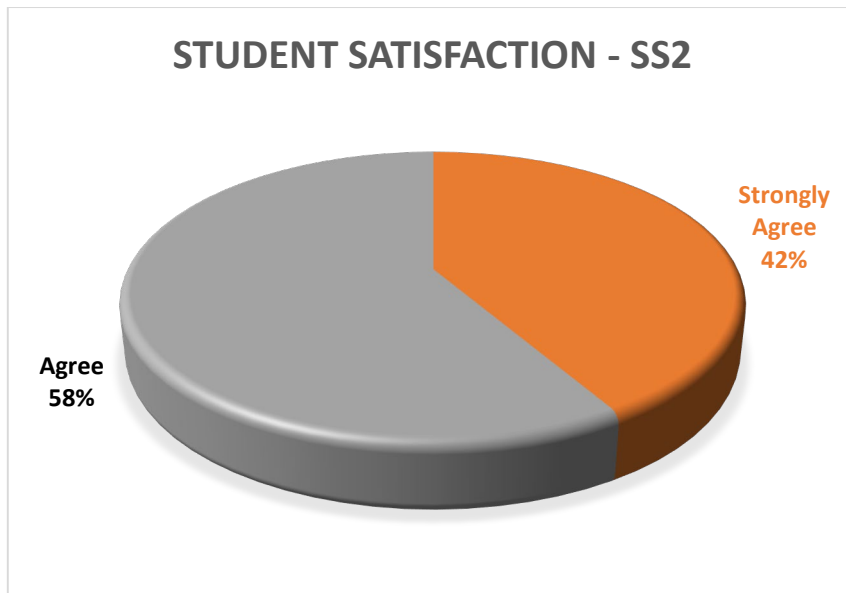


Fig. 4.42 Likert scale rating on able to understand through VR class

Majorly 58 % agreed that they were able to understand the lesson when learnt through VR and 41% strongly agreed with 1 % disagreement. 1 % being negligible, with a total 99% acceptance, it can be inferred that students were able to understand the subject better when they learn it through VR, VR being immersive gives the students better understanding.

SS3:

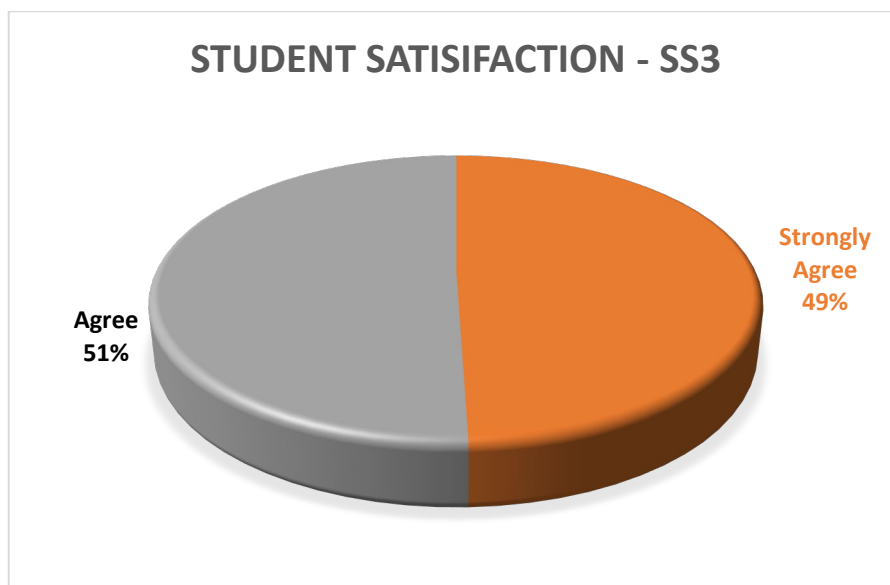


Fig. 4.43 Likert scale rating on don't feel sleepy when learnt through VR

SS3: I don't feel sleepy when learnt through VR (the question has been paraphrased from "I feel sleepy when learn through VR "for analysis purpose and the values are entered in accordance to the students' responses).

49 % of the students agreed that they don't feel sleepy and 48 % of the students strongly agreed they don't feel sleepy and 2 % disagreed with it, the disagreement means that they get sleep when they learn through Vr. Majorly 97% of the students have accepted that they don't get sleep by wearing a VR kit and learning the subject remotely without any real time teacher instruction, the reason could be the colors and animations.

SS4:

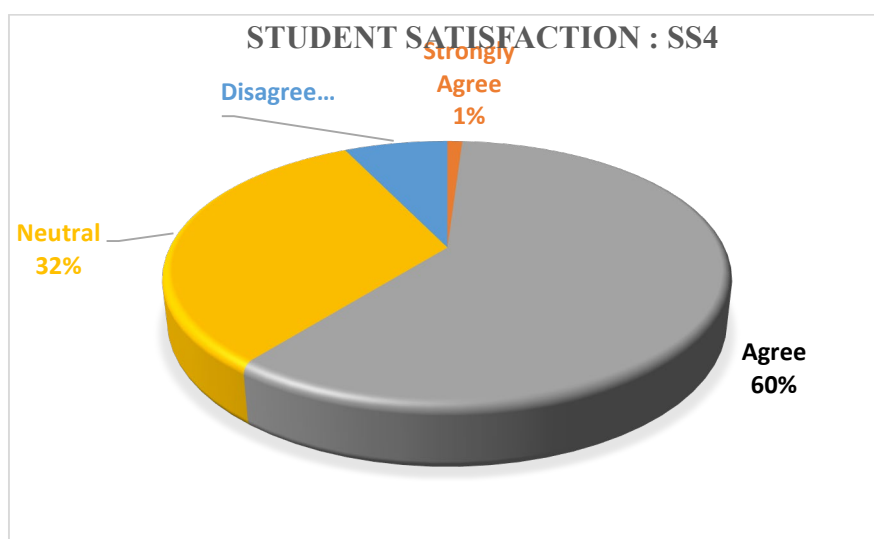


Fig. 4.44 Likert Scale response on "Better understanding on chalk & board method"

SS4: I understand better when I am explained on the board using chalk

Only 1 % of the students strongly agreed to it and 59 % of students agreed that they understand better when they are explained on the board using chalk and 32 % stayed neutral. While 7.5 % of students disagreed to the statement and 1 % strongly disagreed to it meaning, students need their class teacher, who is present physically which will help them to understand and the responses to VR can be added as an advantage to learn it better.

SS5:

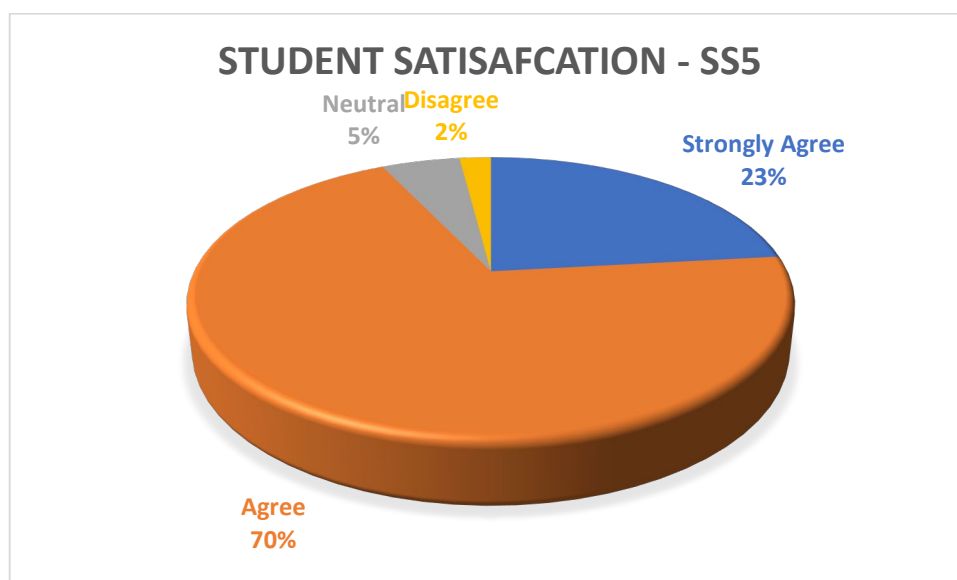


Fig. 4.45 Likert scale response on “Need both Chalk & Board and VR class”

SS5: I need both the teacher class and VR for better understanding

54.5 % of the students agreed that they need both the class teacher and the Vr class for better understanding and 23.5 % strongly agreed to it. 5 % stayed neutral and 2 % disagreed to it. An average of 78 % of students is in acceptance to SS5, the reason could be, the teacher will be physically present in the classroom, so any doubts or clarity they can ask to the teacher and clarify it immediately, also they need VR class since it is interesting and the concepts can be easily understood through simple animations using colors.

SS6:

SS6: Attending VR class leads to better knowledge acquisition

60.5% of the students agreed that they were able to understand better and 39.5 % of the students strongly agreed to it implying that immersive VR helps students to understand the biological concepts better.

Table 4.28 Likert scale survey responses – Learning Interest

Holistic Student Development	Strongly Agree	Agree	neutral	Disagree	Strongly Disagree	Strongly Agree %	Agree %	Total Acceptance %
LI1	123	77	0	0	0	61.5%	38.5%	100
LI2	172	28	0	0	0	86%	14%	100
LI3	150	50	0	0	0	75%	25%	100
LI4	94	28	31	15	32	47%	14%	61

LI: Interest to come to school if class is taken in VR

LI1:

LI1: Learning subject in VR is interesting to me, I will come to school on that day

61.5 % Students strongly agreed that they will come to school if class is taken in VR, since it is interesting and 38.5% of students agreed to it. The results demonstrate that the implementation of VR technology positively affects student attendance. Students exhibited heightened motivation to attend school on days when lessons were delivered via virtual reality, indicating that the incorporation of VR enhances interest, engagement and willingness to learn.

LI2:

LI2: I will not take leave if there is a VR class

86 % of Students strongly agreed that they will not take leave if there is a VR class and 14 % of students agreed to it implying a reduced likelihood of taking leave on days with VR lessons, suggesting that VR stimulate interest and foster anticipation for learning. This indicates that VR as an instructional resource not only enhances comprehension but also favourably affects classroom engagement and attendance.

LI3:

LI3: Learning through VR is like reading a story book, it is interesting, I will come to school 75% of Students strongly agreed that Learning through VR is like reading a story book, interesting and they will come to school if Vr class is there and 25 % of students agreed to it emphasizing how entertaining and interesting it is. Story books always take us into its control through its colourful sequenced images, helping us to remember it easily similarly animated

VR content increases interest and it will be easy to recollect keeping the pictures and animations in mind.

LI4:

LI4: I will come to school if there is a VR Class, I like to learn through VR (the question has been paraphrased from I will not come to school if there is a VR Class, I don't like to learn through VR "for analysis purpose and the values are entered in accordance to the students' responses).

47 % Students strongly agreed that they will come to school if there is a VR Class and have liking to learn through VR and 14 % of students agreed to it neutral indicating that VR -based lessons enhanced their motivation to attend school and also learning via VR is pleasurable and engaging, fostering a desire to participate in class a 15.5 % of students stayed neutral. Neither agreed nor disagreed, possibly they like VR classes but when it comes to attending the school Students may like animation classes (positive attitude), but when it comes to attending school, other factors like family, health, transportation, motivation, come into play.

Discussion:

The categorical variable analysis in this study provides a rich understanding of students' attitudes and perceptions toward Virtual Reality (VR)-based learning, specifically in the context of studying the human respiratory system. The frequency distribution of responses reveals overwhelmingly positive feedback from students across various dimensions, including interest, engagement, comfort, clarity and motivation, while also identifying minimal negative reactions related to discomfort or confusion.

A significant portion of students—**94.5% gave a total acceptance** that "classes taken using VR is interesting," demonstrating a near-unanimous acceptance of VR as an engaging teaching tool, acceptance for VR classes followed by **86.5% gave total acceptance** "they don't feel bored in a VR class ", demonstrating VR as an interesting tool for active learning. This strong positive sentiment is consistent across several core items: **96.5%** of students accepted that VR helps students to look closely the lungs in a bigger size, which is helping them to remember the subject, **84.5%** of students accepted that VR class helps to recollect the shape and parts of lungs easily demonstrating VR learning is a user friendly method which helps to overcome

learning difficulties. This supports the idea that 3D visualization makes abstract biological concepts more concrete and accessible, particularly for middle school learners.

The emotional and physical comfort of using VR was also investigated. **100%** of students accepted that learning through VR is interesting and they will come to school if there is a VR class. This demonstrates that despite the novelty of the technology, most students adapted to it easily and found it conducive to learning. Regarding the simplicity and clarity of content delivery, **70.5 % of student acceptance** indicates that VR helped simplify complex information in a manner that was easy to follow and comprehend.

On the contrary, when it comes to physical discomfort, only **20%** of students *agreed* that they experienced headaches, while **73%** suggested that health concerns are minimal. Similarly, feeling sleepy when learning through VR, 97% of students disagreed to it and 2 % agree, indicating that most students find VR interactive and its visually engaging information, captivates students' attention and retains their interest throughout the session

Behavioral motivation and class participation were also positively influenced. When asked whether VR made them interested in attending school 61.5 % strongly agreed and 38.5 % agreed totaling to 100 % of acceptance that VR classes are interesting. Moreover, **86% strongly agreed and 14% agreed** that they would not take leave if there was a VR class, showing that VR has potential to reduce absenteeism. The sense of narrative immersion was also strong, as **75%** of students *strongly agreed* and 25 % agreed that learning through VR is like reading a storybook, making the subject interesting to learn.

The categorical data demonstrates robust support for VR-based learning. Students find it interesting, memorable and easy to understand, with minimal complaints about discomfort or confusion. The results strongly support the integration of VR into middle school science instruction as a tool for improving engagement, understanding and motivation.

4.9.3 One Way ANOVA – Holistic Student Development vs Zones

Table 4.29 One Way ANOVA – Student Engagement vs Zones

Descriptives						
Holistic Student Development	Zones	Mean	SD	Std. Error	F	P.
Student Engagement	North Chennai	14.1	1.066	0.126	2.055	0.131
	Central Chennai	14.2	1.116	0.132		
	South Chennai	14.5	0.869	0.115		
	Total	14.3	1.038	0.073		
Learning Resilience (Overcoming Learning Difficulties)	North Chennai	18.4 ^a	1.378	0.162	3.481	0.033*
	Central Chennai	18.5 ^a	1.382	0.164		
	South Chennai	19 ^b	1.217	0.161		
	Total	18.6	1.352	0.096		
Student Satisfaction	North Chennai	22.7 ^a	1.997	0.235	7.891	<0.001**
	Central Chennai	22.8 ^a	1.76	0.209		
	South Chennai	23.8 ^b	1.428	0.189		
	Total	23	1.826	0.129		
Learning Interest	North Chennai	18.6 ^a	1.527	0.18	9.618	<0.001**
	Central Chennai	18.6 ^a	1.398	0.166		
	South Chennai	19.5 ^b	0.782	0.104		
	Total	18.9	1.363	0.096		
Overall Holistic Student Development	North Chennai	73.8 ^a	4.751	0.56	9.538	<0.001**
	Central Chennai	74.1 ^a	4.359	0.517		
	South Chennai	76.8 ^b	3.075	0.407		
	Total	74.8	4.368	0.309		

** Denotes significance at 1 % level; *Denotes significance at 5 % level

4.9.3.1 Student Engagement vs Zones

HYPOTHESIS 15:

Null Hypothesis H_0 : There is no significant difference in students' Engagement across the 3 zones.

Student Engagement: One Way Anova test reveals that there is no significant difference in the student engagement level with regard to all the three zones , north , central and south , north zone mean = 14.1, central zone mean = 14.2 and south zone mean value = 14.5, the f value = 2.055 and p value = 0.131 indicating that we *accept the null hypothesis* since p value is more than 0.05 ($p > 0.05$).

4.9.3.2 Learning Resilience vs Zones

HYPOTHESIS 15:

Null Hypothesis H_0 : There is no significant difference in Learning Resilience across the 3 zones.

There is a significant difference in Learning Resilience among the 3 zones. South zone students (mean = 19) were highly engaged when compared to north zone (mean = 18.4) and central zone (mean = 18.5). North and Central zones showed near equal responses and there is no significant difference among the two zones in regard to Learning Resilience. The P value being less than 0.033 we *reject the null hypothesis at a significant level of 5%* stating that there is a significant difference between zones with respect to Learning Resilience.

4.9.3.3 Student Satisfaction vs Zones

HYPOTHESIS 16:

Null Hypothesis H_0 : There is no significant difference in Student Satisfaction across the 3 zones.

There is a significant difference in Student Satisfaction among the 3 zones. South zone students (mean = 23.8) were highly engaged when compared to north zone (mean = 22.7) and central zone (mean = 22.8). North and Central zones showed nearing equal responses and there is no significant difference between the two zones regarding Student Satisfaction. The P value being less than 0.001 we *reject the null hypothesis at significance level of 1 %* stating that there is a significant difference between zones with respect to student satisfaction.

4.9.3.4 Learning Interests vs Zones

HYPOTHESIS 17:

Null Hypothesis H_0 : There is no significant difference among the three zones of Chennai with respect to Learning Interests

A significant difference was found in Learning Interest among the 3 zones. South zone students (mean = 19.5) were able to overcome learning difficulties better when compared to north zone (mean = 18.6) and central zone (mean = 18.6). North and Central zones showed equal responses and there is no significant difference among the two zones in regard to Interest to Learn. The P value being less than 0.001 ($p < 0.001$) we *reject the null hypothesis at a significance level of 1 %*, stating that there is a significant difference between zones with respect to Learning Interests

The Overall Holistic Student Development signifies that the south Zone students performed better when compared to north and central zone students. Overall South zone mean value = 76.8, Overall North zone mean value = 73.8, Overall Central zone mean value = 74.1, implies that south zone has outperformed in almost all the factors related to holistic student development except for student satisfaction.

The South Zone includes areas like Myapore, T.Nagar, Adayar which are highly developed areas and students from affluent neighbourhoods are more likely to benefit from nurturing family situations, which include resources such as private tutoring, internet connectivity and a culture that prioritises academic success.

4.9.4 Pearson Correlation

4.9.4.1 Pearson Correlation between Student Engagement & Learning Resilience

HYPOTHESIS 18:

Null Hypothesis H_0 : There is no significant correlation between Student Engagement & Learning Resilience

Table 4.30 Correlations

Pearson Correlations				
	Student Engagement	Learning Resilience (Overcoming Learning Difficulties)	Student Satisfaction	Learning Interest
Student Engagement	1.000	0.547**	0.490**	0.468**
Learning Resilience (Overcoming Learning Difficulties)		1.000	0.405**	0.319**
Student Satisfaction			1.000	0.620**
Learning Interest				1.000
**. Correlation is significant at the 0.01 level (2-tailed).				

The correlation coefficient between student engagement and overcoming learning difficulties is 0.547, which indicate ($0.547^2 = 0.2991$), 29.97 percentage positive relationships between student engagement and overcoming learning difficulties and it is significant at 1 % level. Hence, *we reject the null hypothesis* and accept the alternate hypothesis that there is a correlation between student engagement and overcoming learning difficulties.

4.9.4.2 Pearson Correlation between Student Engagement & Student Satisfaction

HYPOTHESIS 19:

Null Hypothesis H_0 : There is no significant correlation between Student Engagement & Student Satisfaction

The correlation coefficient between student engagement and student satisfaction is 0.490, indicating a 24.01% positive a relationship between the two variables, significant at the 1% level. Hence, *we reject the null hypothesis* and accept that there is a correlation between student engagement and student satisfaction.

4.9.4.3 Pearson Correlation between Student Engagement & Interest toward learning

HYPOTHESIS 20:

Null Hypothesis H_0 : There is no significant correlation between Student Engagement & Interest towards Learning

The correlation coefficient between student engagement and interest towards learning is 0.468, which indicates ($0.468^2 = 0.2190$), 21.09 percentage positive relationships between student engagement and interest towards learning and is significant at 1 % level and hence *we reject the null hypothesis* and accept that there is a correlation between student engagement and Interest towards Learning

4.9.4.4 Pearson Correlation between Student Engagement & Interest toward learning

HYPOTHESIS 21:

Null Hypothesis H_0 : There is no significant correlation between Overcoming Learning Difficulties and student satisfaction

The correlation coefficient between Overcoming Learning Difficulties and student satisfaction is 0.405, indicating a 16.40% positive relationship ($0.405^2 = 0.1640$) that is significant at the 1% level. Consequently, we *reject the null hypothesis* and accept the existence of a correlation between the two variables.

4.9.4.5 Pearson Correlation between Learning Resilience vs Interest towards Learning

HYPOTHESIS 22:

Null Hypothesis H_0 : There is no significant correlation between Overcoming Learning Difficulties and Interest towards learning

The correlation coefficient between Overcoming Learning Difficulties and interest in learning is 0.319, indicating a 10.17% positive association between the two variables, which is significant at the 1% level and hence we *reject the null hypothesis* and accept that there exists a correlation between the two variables.

4.9.4.6 Pearson Correlation between Satisfaction and Interest towards Learning

HYPOTHESIS 23:

Null Hypothesis H_0 : There is no significant correlation between student satisfaction and Interest towards learning

The correlation coefficient between student satisfaction and interest in learning is 0.620, indicating a 38.44% positive relationship between the two variables, which is significant at the 1% level. Therefore, we *reject the null hypothesis* and accept that a relationship exists between student satisfaction and interest in learning.

Discussion:

The positive correlation between student engagement vs Overcoming Learning Difficulties, Student Satisfaction, Interest towards learning indicates us that when students are engaged in their learning, they can overcome difficulties in the learning which leads to student satisfaction, making the student confident to discuss among their peers and improved communication skills. The positive correlation between overcoming learning difficulty vs student satisfaction and interest to learn indicates that when students can overcome their difficulty in learning they will feel more satisfied motivating the student to come to school for learning. The positive correlation between student satisfaction and learning interest implies that a satisfied student will tend to attend classes and will come to school.

4.9.5 Multiple Regression Analysis

Introduction:

Regression is the examination of the statistical relationship among two or more variables. Simple regression involves two variables: one independent variable that affects the behaviour of a dependent variable. When more than two independent variables are present, the analysis of their interrelationships is termed multiple correlations and the equation representing this relationship is known as the multiple regression equation.

Regression analysis aims to build an appropriate mathematical equation to ascertain the values of a dependent variable in relation to independent factors. This aims to examine the correlation between variable Y and a set of supplementary variables $X_1, X_2, X_3, \dots, X_n$, with the predominant linear equation expressed as $Y = b_1 X_1 + b_2 X_2 + \dots + b_n X_n + b_0$. Y is the

dependent variable to be ascertained. $X_1, X_2, \dots, X_n$ represent the known variables for which predictions are to be generated, while $b_1, b_2, \dots, b_0$ denote the coefficients associated with these variables.

Regression:

Table 4.31 Regression Analysis Output: Constant and Predictor Coefficients

Coefficients					
	Unstandardized Coefficient		Standardized Coefficient	t value	P value
	B	Std. Error	(Beta)		
Constant	13.941	2.172		6.419	<0.001
X1	0.486	0.122	0.285	3.981	<0.001
X2	0.089	0.14	0.044	0.637	0.525
X3	0.547	0.111	0.351	4.944	<0.001
X4	0.038	0.087	0.033	0.443	0.658
X5	0.214	0.108	0.139	1.978	0.049
X6	0.096	0.088	0.076	1.095	0.275

Independent Variables are $X_1, X_2, X_3, X_4, X_5, X_6$

Dependent Variable is the scores of Post Test VR

X_1 being Cognitive Load, X_2 – Student Engagement, X_3 – Overcoming Learning Difficulties, X_4 – Student Satisfaction, X_5 Interest to Learn, X_6 Peer interaction & communication

1. Dependent Variable : Post Test VR
2. Independent Variable : Cognitive Load
Student Engagement
Overcoming Learning Difficulties

Student Satisfaction

Interest to Learn

Peer Communication

Multiple R value : 0.683
R square Value : 0.466
F value : 28.066
P value : <0.001

Regression is , for each and every difference in the independent variable X1, X2, the result of the dependent variable Post Test Result of VR will vary.

4.9.5.1 Independent variable on Dependent variable

HYPOTHESIS 24:

Null Hypothesis H_0 : Cognitive load does not significantly predict Post Test VR scores

Table 4.32 Regression Analysis of Independent variable on Dependent variable

Dependent Variable	Independent Variable	R	R Square	F	Sig
Post Test VR	Cognitive Load	0.683	0.466	28.066	<0.001
	Student Engagement				
	Learning Resilience (Overcoming Learning Difficulties)				
	Student Satisfaction				
	Interest to Learn				
	Peer Learning & communication				

The multiple correlation coefficient is 0.683 measures the degree of relationship between the actual values of the Post Test VR, because the predicted values are obtained as a linear

combination of Cognitive Load (X1), Student Engagement(X2), Learning Resilience (Overcoming Learning Difficulties) (X3), Student satisfaction(X4), Interest to Learn(X5) and Peer Learning & communication(X6). The coefficient value of 0.683 indicates that the relationship between the results of Post Test VR and the 6 independent variables is quite strong and positive.

The Coefficient of Determination R-square quantifies the goodness-of-fit of the estimated Sample Regression Plane (SRP) by indicating the fraction of variation in the dependent variable elucidated by the fitted sample regression equation. The R square value of 0.466 indicates that approximately 46.6% of the variance in Post Test VR results is accounted for by the estimated SRP, which employs Cognitive Load, Student Engagement, Overcoming Learning Difficulties, Student Satisfaction, Interest to Learn and Peer Learning & Communication as independent variables, with the R square value being significant at the 1% level.

The multiple regression equation is

$$Y = 13.941 + 0.486 X_1 + 0.089 X_2 + 0.547 X_3 + 0.038 X_4 + 0.214 X_5 + 0.096 X_6$$

Here the coefficient of X_1 is 0.486 represents the partial effect of Cognitive Load on the mark score of Post Test VR holding the other variables as constant. The estimated positive sign implies that such effect is positive that results of Post Test VR would increase by 0.486 for every unit increase in Cognitive Load and this coefficient is significant at 1 % level. P value being <0.001 *we reject the null hypothesis* and accept that ***Cognitive load significantly predicts Post Test VR scores.***

4.9.5.2 Student engagement predicts Post Test VR scores

HYPOTHESIS 25:

Null Hypothesis H_0 : Student engagement does not significantly predict Post Test VR scores

The coefficient for student involvement is $X_2 = 0.089$, signifying that each unit increase in student engagement corresponds to a 0.089-point increase in Post Test VR results, while adjusting for other variables. This connection lacked statistical significance ($p = 0.525$). The calculated correlation between student involvement and Post Test VR performance was

positive; nevertheless, it lacked statistical significance in our sample ($p = 0.525$), therefore ruling out any conclusion regarding the impact of student engagement on Post Test VR scores, hence ***accept the null hypothesis***. Subsequent research utilizing larger samples or different metrics of student engagement may elucidate this association.

4.9.5.3 Overcoming Learning Difficulties predicts Post Test VR scores

HYPOTHESIS 26:

Null Hypothesis H_0 : Learning Resilience (Overcoming Learning Difficulties) does not significantly predict Post Test VR scores

The coefficient of X_3 is 0.547 represents the partial effect of Overcoming Learning Difficulties on the test scores of Post Test VR holding the other variables as constant. The estimated positive sign implies that such effect is positive that results of Post Test VR would increase by 0.547 for every unit increase in Overcoming Learning Difficulties and this coefficient is significant at 1 % level. P value being less than 0.001 ($p < 0.001$) we ***reject the null hypothesis*** and accept that Learning Resilience (Overcoming learning difficulties) will increase the Post Test VR scores

4.9.5.4 Student Satisfaction predicts Post Test VR scores

HYPOTHESIS 27:

Null Hypothesis H_0 : Student Satisfaction does not significantly predict Post Test VR scores

The coefficient for student satisfaction is $X_4 = 0.038$, indicating that every unit increase in student satisfaction was associated with a 0.038-point increase in Post Test VR scores, controlling for other variables. However, this association was not statistically significant ($p = 0.658$). Although the estimated association between student engagement and Post Test VR performance was positive, it was not statistically significant in this sample ($p = 0.525$), so we cannot conclude that student satisfaction affects Post Test VR scores, hence we ***accept the null hypothesis*** that Student Satisfaction does not significantly predict Post Test VR scores

4.9.5.5 Interest to come to school predicts Post Test VR scores

HYPOTHESIS 28:

Null Hypothesis H_0 : Interest in coming to school does not significantly predict Post Test VR scores

The coefficient of X_5 is 0.214 represents the partial effect of Interesting to come to school on the test scores of Post Test VR holding the other variables as constant. The estimated positive sign implies that such effect is positive that results of Post Test VR would increase by 0.214 for every unit increase in Interest to come to school and this coefficient is significant at 5 % level. P value = 0.045, signifies that Interest to come to school predicts Post Test VR scores and we *reject the null hypothesis* at 5 % significance level.

4.9.5.6 Peer Learning predicts Post Test VR scores

HYPOTHESIS 29:

Null Hypothesis H_0 : Peer learning does not significantly predict Post Test VR scores

The coefficient for Peer Learning & Communication is $X_6 = 0.096$, signifying that each unit increase in student satisfaction corresponds to a 0.096-point increase in Post Test VR results, while controlling for other variables. This connection lacked statistical significance ($p = 0.275$).

The calculated correlation between Peer Learning & Communication and Post Test VR performance was positive; nevertheless, it lacked statistical significance in this sample ($p = 0.525$), consequently, any conclusion regarding the influence of peer learning and communication on post-test VR scores is ruled out.

4.9.6 Structural Equation Model

The complex relationships among the variables are examined with Structural Equation model through statistics. It is a combination of factor analysis and regression analysis. In our research, SEM was employed to explore the relationships between the independent variables, VR teaching and dependent variable student satisfaction, student engagement, learning resilience (overcoming learning difficulty), learning interest, providing a comprehensive understanding of how these constructs interact.

Variable Summary (Group number 1)

Model contains the following variables (Group number 1)

I - Observed, endogenous variables (Dependent variable)

LI1- Attending School for VR class

LI2- Don't take leave for VR class

LI3- VR is like reading a story book

LI4- Not come to school

LR1- Recollect shapes

LR2- View bigger size

LR3- Feel comfortable

LR4-Simple and easy

SE1-Interesting

SE2- Not bored

SE3- Feeling encouraged

SS1-No headache

SS2- Understanding Difficulty

SS3- Feeling sleepy

SS4- Not understanding

SS5- Need both modes

SS6- Better understanding

II - Unobserved, endogenous variables

SE-Student Engagement

SS- Student Satisfaction

Unobserved, exogenous variables:

LI, ϵ_1 to ϵ_{19} , LR

ϵ_3

e4
e5
e6
e7
e8
e9
e10
e11
e12
e13
e14
e15
e16
e17
e18
e19
LR

Table 4.33 Variable counts (Group number 1)

Number of variables in model:	40
Number of observed variables:	17
Number of unobserved variables:	23
Number of exogenous variables:	21
Number of endogenous variables:	19

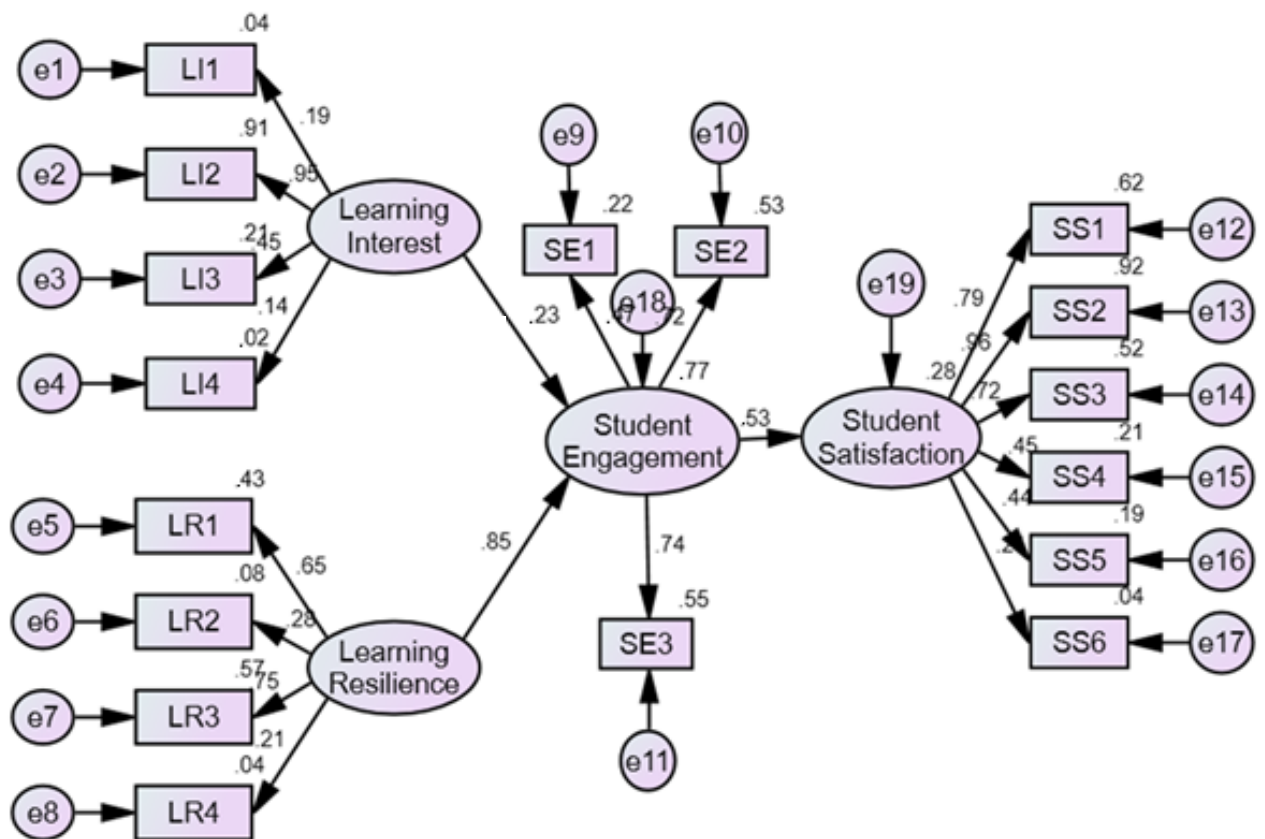


Fig. 4.46 SEM MODEL

Estimates (Group number 1 - Default model)

Scalar Estimates (Group number 1 - Default model)

Maximum Likelihood Estimates

Regression Weights: (Group number 1 - Default model)

Table 4.34 – Regression Coefficients (Unstandardized and Standardized) for the Variables Studied

Variables			Unstandardized co-efficient (B)	S.E of B	Standardized co-efficient (Beta)	t value	P value
LI1	<---	LI	0.041	0.018	0.188	2.320	0.020*
LI2	<---	LI	0.330	0.066	0.951	5.004	<0.001* *
LI3	<---	LI	0.197	0.048	0.454	4.116	<0.001* *
LI4	<---	LI	0.204	.117	.135	1.989	0.048*
LR1	<---	LR	0.316	.035	.655	9.002	<0.001* *
LR2	<---	LR	0.073	.020	.285	3.611	<0.001* *
LR3	<---	LR	0.372	.036	.752	10.362	<0.001* *
LR4	<---	LR	0.258	.098	.209	2.625	0.009**
SE1	<---	SE	1.000	-	.468	-	<0.001* *
SE2	<---	SE	2.144	.370	.725	5.800	<0.001* *
SE3	<---	SE	2.093	.358	.741	5.839	<0.001* *
SS1	<---	SS	1.000	-	.788	-	<0.001**
SS2	<---	SS	0.696	.050	.958	14.054	<0.001* *
SS3	<---	SS	0.596	.054	.722	10.971	<0.001* *

Variables			Unstandardized coefficient (B)	S.E of B	Standardized coefficient (Beta)	t value	P value
SS4	<---	SS	0.602	.093	.455	6.461	<0.001* *
SS5	<---	SS	0.595	.096	.436	6.171	<0.001* *
SS6	<---	SS	0.117	.040	.212	2.916	0.004**
SE	<---	LI	0.037	.014	.228	2.672	0.008**
SE	<---	LR	0.138	.024	.849	5.729	<0.001* *
SS	<---	SE	2.460	.520	.532	4.729	<0.001* *

From the above table, Unstandardized coefficient of LI 1 Attending School when VR class is there on LI – Learning Interest is 0.041 represents the partial effect of Learning Interest on Attending School for VR class, holding the other path variable as constant. The estimated positive sign implies that such effect is positive that Learning Interest would increase by 0.04 for every unit increase in LI1 Attending School for VR class and the coefficient value is significant at 5 % level.

Unstandardized coefficient of LI2 Not take leave for VR class on LI-Learning Interest is 0.330 represents the partial effect of Learning Interest on Not take leave for VR class, holding the other path variable as constant. The estimated positive sign implies that Learning Interest would increase by 0.330 for every unit increase in Not take leave for VR class and the coefficient value is significant at 1 % level.

Unstandardized coefficient of LI3 VR is like reading a story book on LI-Learning Interest is 0.197 represents the partial effect of Learning Interest on VR is like reading a story book, holding the other path variable as constant. The estimated positive sign implies that Learning Interest would increase by 0.197 for every unit increase in VR is like reading a story book and the coefficient value is significant at 1 % level.

Unstandardized coefficient of LI4 – liking to learn through VR on LI-Learning Interest is 0.204 represents the partial effect of Learning Interest on LI4, holding the other path variable as constant. The estimated positive sign implies that Learning Interest would increase by 0.204 for every unit increase in “liking to learn through VR” and students responded that they agree to it and they like to come to school if there is a VR class and the coefficient value is significant at 5 % level.

Based on the Standardized Coefficient, Not take leave for VR class(0.951) is the most influencing path in this SEM model, followed by Learning in VR is like reading a story book and it is interesting(0.454) , followed by Learning subject is Interesting to me and I will come to school(0.188) and the last being LI4(0.135)

Unstandardized coefficient of LR 1 Recollect shapes on LR – Learning Resilience is 0.316 represents the partial effect of Learning Resilience on VR class helps to recollect the shape and parts of lungs easily holding the other path variable as constant. The estimated positive sign implies that such effect is positive that Learning Resilience would increase by 0.316 for every unit increase in LR1 Recollect shapes and the coefficient value is significant at 1 % level.

Unstandardized coefficient of LR2 View bigger size on LR – Learning Resilience is 0.073 represents the partial effect of Learning Resilience on VR helps me to look closely the lungs in a bigger size, it helps me to remember, holding the other path variable as constant. The estimated positive sign implies that such effect is positive that Learning Resilience would increase by 0.073 for every unit increase in LR2 View bigger size and the coefficient value is significant at 1 % level.

Unstandardized coefficient of LR3 Feel comfortable on LR – Learning Resilience is 0.372 represents the partial effect of Learning Resilience on I feel comfortable to see in VR and learn the lesson, holding the other path variable as constant. The estimated positive sign implies that such effect is positive that Learning Resilience would increase by 0.372 for every unit increase in LR3 Feel comfortable and the coefficient value is significant at 1 % level.

Unstandardized coefficient of LR4 Simple and Easy on LR – Learning Resilience is 0.258 represents the partial effect of Learning Resilience on I find it simple and easy to learn in VR, holding the other path variable as constant. The estimated positive sign implies that such effect is positive that Learning Resilience would increase by 0.258 for every unit increase in LR4 Simple and easy and the coefficient value is significant at 1 % level.

Based on the Standardized Coefficient, Feeling comfortable in VR (0.752) is the most influencing path in this SEM model, followed by I am able to recollect the shapes that is seen in VR (0.655) , followed by I am able to view the shapes in bigger size, which helps to recollect (0.285) and the last being it is simple and easy(0.209)

Unstandardized coefficient of SE1 Interesting on SE – Student Engagement is 1.000 represents the partial effect of Student Engagement on Class taken using VR is interesting to me, holding the other path variable as constant. The estimated positive sign implies that such effect is positive, that Student Engagement would increase by 1.000 for every unit increase SE1 Interesting and the coefficient value is significant at 1 % level.

Unstandardized coefficient of SE2 Not bored on SE – Student Engagement is 2.144 represents the partial effect of Student Engagement on Class taken in VR is not boring, holding the other path variable as constant. The estimated positive sign implies that such effect is positive that Student Engagement would increase by 2.144 for every unit increase SE2 Not bored and the coefficient value is significant at 1 % level.

Unstandardized coefficient of SE3 Feeling encouraged on SE – Student Engagement is 2.093 represents the partial effect of Student Engagement on feeling encouraged when VR class is there and it helps to remember the subjects, holding the other path variable as constant. The estimated positive sign implies that such effect is positive that Student Engagement would increase by 2.093 for every unit increase SE3 Feeling encouraged and the coefficient value is significant at 1 % level.

Based on the Standardized Coefficient, Feeling encouraged to come to school if VR class is there (0.741) is the most influencing path in this SEM model, followed by I don't feel bored when I learn in VR (0.725), followed by Interesting (0.468)

Unstandardized coefficient of SS1 No Headache on SS – Student Satisfaction is 1.000 represents the partial effect of Student Satisfaction on I don't get headache when I use VR and learn, holding the other path variable as constant. The estimated positive sign implies that such effect is positive that Student Satisfaction would increase by 1.000 for every unit increase SS1 and the coefficient value is significant at 1 % level.

Unstandardized coefficient of SS2 Understanding Difficulty on SS – Student Satisfaction is 0.696 represents the partial effect of Student Satisfaction on SS2, holding the other path variable as constant. The estimated positive sign implies that such effect is positive that Student

Satisfaction would increase by 0.696 for every unit increase SS2 I am not able to understand when learnt through VR and student response has been noted that they were able to understand when they learnt through VR through their responses meaning better understanding and the coefficient value is significant at 1 % level.

Unstandardized coefficient of SS3 Don't Feel sleepy on SS – Student Satisfaction is 0.596 represents the partial effect of Student Satisfaction on don't feel sleepy when class in VR, holding the other path variable as constant. The estimated positive sign implies that such effect is positive that Student Satisfaction would increase by 0.596 for every unit increase SS3 they don't feel sleepy when they see in VR by their response and the coefficient value is significant at 1 % level.

Unstandardized coefficient of SS4 No conventional on SS – Student Satisfaction is 0.602 represents the partial effect of Student Satisfaction on I don't understand much when I am explained on the board using chalk, holding the other path variable as constant. The estimated positive sign implies that such effect is positive that Student Satisfaction would increase by 0.602 for every unit increase SS4 and the coefficient value is significant at 1 % level.

Unstandardized coefficient of SS5 Need both modes on SS – Student Satisfaction is 0.595 represents the partial effect of Student Satisfaction on I need both the class teacher class and VR for better understanding, holding the other path variable as constant. The estimated positive sign implies that such effect is positive that Student Satisfaction would increase by 0.595 for every unit increase SS5 and the coefficient value is significant at 1 % level.

Unstandardized coefficient of SS6 Better understanding on SS – Student Satisfaction is 0.117 represents the partial effect of Student Satisfaction on I need both the class teacher class and VR for better understanding, holding the other path variable as constant. The estimated positive sign implies that such effect is positive that Student Satisfaction would increase by 0.117 for every unit increase SS5 and the coefficient value is significant at 1 % level

Based on the Standardized Coefficient, I am able to understand better in Vr than in chalk & board (0.958) is the most influencing path in this SEM model, followed by I don't get headache when in see and learn through VR (0.0.788) , followed by I don't feel sleepy when I see VR (0.722), i don't want conventional method alone(0.455),followed by I need both conventional and VR (0.436), followed by learning through VR is better to understand.

Unstandardized coefficient of SE Student Engagement on LI Learning Interest is 0.037 represents the partial effect of Student Engagement on Learning Interest holding the other path variable as constant. The estimated positive sign implies that such effect is positive that Learning Interest would increase by 0.117 for every unit increase Student Engagement and the coefficient value is significant at 1 % level

Unstandardized coefficient of SE Student Engagement on LR Learning Resilience is 0.138 represents the partial effect of Student Engagement on Learning Resilience holding the other path variable as constant. The estimated positive sign implies that such effect is positive that Learning Resilience – Overcoming Learning Difficulties, they can overcome it positively and would increase by 0.138 for every unit increase Student Engagement and the coefficient value is significant at 1 % level, leaving us with the result that Learning resilience – difficulty level can be overcome by students if they are engaged and if learning is made interesting with VR , the student engagement will increase which will increase the overall performance of the students.

Unstandardized coefficient of SE Student Engagement on SS Student Satisfaction is 2.460 represents the partial effect of Student Engagement on Student satisfaction holding the other path variable as constant. The estimated positive sign implies that such effect is positive that Student Satisfaction would increase by 2.460 for every unit increase Student Engagement and the coefficient value is significant at 1 % level, leaving us with the result that the student will be satisfied if they are engaged in learning through VR.

For the purpose of testing the model fit, null hypothesis and alternative hypothesis are framed

HYPOTHESIS 30:

Null Hypothesis H_0 : The hypothesized model does not have a good fit.

Alternate hypothesis : The hypothesized model has a good fit.

Table 4.35 Model Fit Summary of Structural Equation Model

Model	CMIN	DF	P	CMIN/DF	GFI	AGFI	NFI	CFI	RMR	RMS EA
Default model	410.151	116	.000	3.534	.950	.944	.956	.954	.075	.060

Table 4.36 Model Fit Summary of SEM with references

Indices	Value	Suggested Value
Chi-Square Value	410.151	-
DF	116	-
P Value	0.001	> 0.05 (Hair et al., 1998)
Chi-Square Value /DF	3.534	< 5.00 (Hair et al., 1998)
GFI	0.95	> 0.90 (Hu and Bentler, 1999)
AGFI	0.944	> 0.90 (Hair et al. 2006)
NFI	0.956	> 0.90 (Hu and Bentler, 1999)
CFI	0.954	> 0.90 (Daire et al., 2008)
RMR	0.075	< 0.08 (Hair et al. 2006)
RMSEA	0.06	< 0.08 (Hair et al. 2006)

From the above table it is found that the value of Chi-Square/DF is 3.534 which is less than 5.00 which indicates that the model is perfectly Fit (Hair et.al, 1998). Goodness of Fit Index (GFI) value (0.95) and Adjusted Goodness of Fit Index (0.944) is greater than 0.90 (Hu et.al, 1999, Hair et.al 2006) which represents that it is a good fit. The calculated Normal Fit Index (NFI) value (0.956) and Comparative Fit Index (CFI) value (0.954) indicate that is perfectly fit (Daire et. al) and also it is found that Root Mean Square (RMR) and Root Mean Square Error of Approximation (RMSEA) value is 0.06 which is less than 0.08 which indicates that it is perfectly fit. (Hair et. al. 2006). P value being <0.001 the *null hypothesis is rejected at a significant level of 1 %*, meaning it is highly significant and the *model is perfectly Fit*.

Discussion:

Students who have participated in virtual reality (VR) classes have reported that they would not skip school in the event of a VR class and that the technology is engaging because it is similar to reading a book. These results are derived from the structural equation modelling (SEM) approach. Since the students could see the various lung components in a larger format, they found it much easier to memorize the shapes and they also reported feeling more at ease overall. Students expressed their enthusiasm for virtual reality (VR) classes, saying that they look forward to going to school and that they never get bored learning in VR. In comparison to traditional classroom instruction using chalk and board, students reported higher levels of understanding when using virtual reality (VR). Additionally, students reported that VR did not cause them any headaches or make them drowsy during class and many students felt that VR and traditional methods of instruction were complementary rather than competing. In the end, students can overcome learning difficulties with engagement and if virtual reality (VR) makes studying attractive, their engagement will grow, leading to improved overall performance.

The above results are consistent with Self-Determination Theory (Deci & Ryan, 1985) and recent research (Huang et al., 2025), demonstrating that immersive technology fosters autonomy, competence and relatedness, consequently improving student engagement and learning. These findings corroborate previous studies indicating that immersive learning environments enhance satisfaction, intrinsic motivation and interest in school attendance (Nguyen-Viet, 2025).”

4.10 Analysis of Collaborative and Social Learning Outcomes Through VR

This objective seeks to understand whether the use of Virtual Reality (VR) in teaching the respiratory system promotes collaborative and social learning among middle school students, thereby enhancing peer learning, teamwork and communication skills. Collaborative learning refers to the process where students work together, share ideas and collectively solve problems, while social learning occurs through observation, imitation and interaction with peers (Bandura, 1986). The immersive and engaging nature of VR can create opportunities for both forms of learning by sparking discussion, encouraging mutual explanation and stimulating curiosity among students.

Impact of VR on Student Learning and Interaction

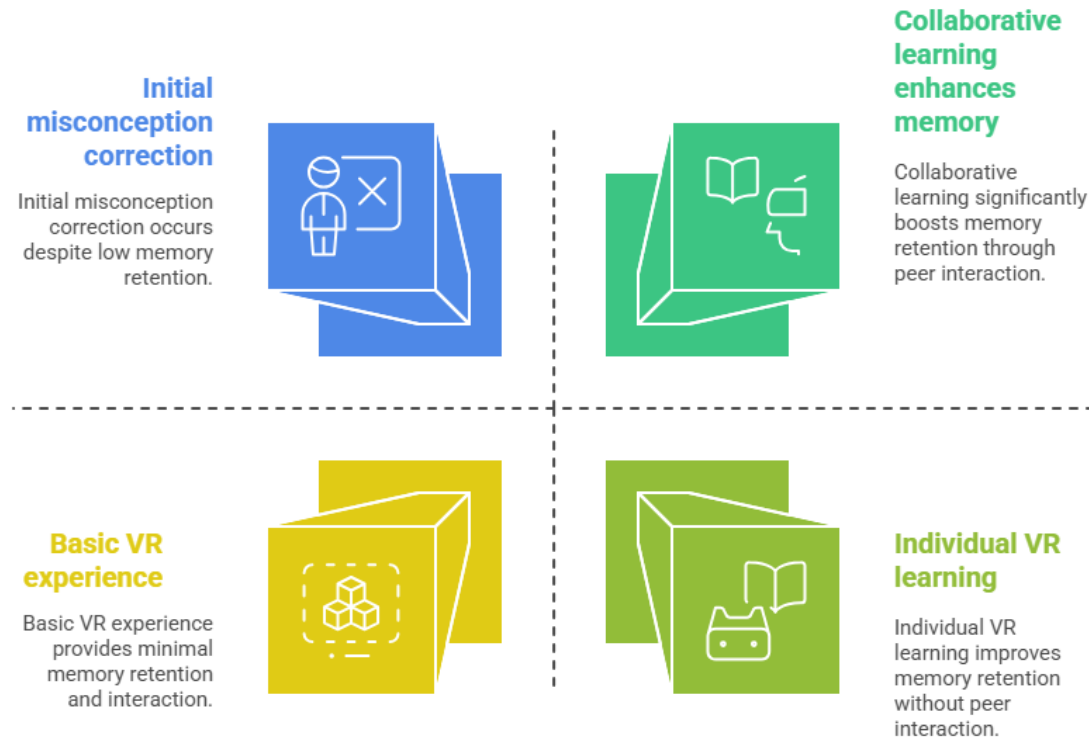


Fig. 4.47 Impact of VR on Student Learning and Interaction

4.10.1 Social Learning leads to Peer Interaction & Communication

HYPOTHESIS 31:

Null Hypothesis H_0 : There is no significant difference among the students with regard to social learning leading to peer interaction and the development of teamwork and communication skills when learnt through VR.

To investigate this, a **survey** was conducted with the students after the VR session. The students were asked a series of structured questions that explored whether they recollected and discussed the VR content with friends, corrected misunderstandings through peer conversations and felt confident enough to explain what they learned to others. Responses revealed that a majority of the students *agreed* or *strongly agreed* that they found the topic more interesting and understandable through VR. Several students mentioned that seeing the process visually helped them remember it more vividly, which led them to initiate discussions with their peers. Others reported that being able to explain the content to their classmates made them feel like “small teachers,” a phrase that reflects self-efficacy and pride in their learning.

The peer interaction also helped rectify misconceptions. Some students admitted that they initially misunderstood certain aspects of the respiratory system but were able to correct those errors after discussing them with friends. This indicates that collaborative dialogue reinforced accurate understanding and promoted deeper cognitive processing. Furthermore, many students stated that the act of discussing what they saw with peers helped them remember the topic better and enhanced their ability to articulate it clearly key indicators of both retention and communication development.

To further validate these findings, **interviews with teachers** were conducted. *Ms. Anupriya*, a science teacher from a Government Higher Secondary School, noted a visible increase in student engagement during and after the VR session. She observed students voluntarily discussing the content, showing enthusiasm and even encouraging peers to participate. Students who were usually hesitant began answering questions confidently, indicating improved self-expression and social confidence. She also reported that students showed increased motivation and were more active in class discussions post-VR.

Ms. Meera, science teacher involved in the study, shared similar insights. She highlighted that students were eager to experience VR and, more importantly, immediately initiated conversations with peers after the session. They appeared genuinely interested and emotionally invested in the learning experience. According to her, many students confidently responded when asked to explain what they had seen, showing that VR not only stimulated interest but also encouraged knowledge sharing and peer teaching.

In conclusion, the data from focus groups, peer response sheets and teacher interviews strongly support the notion that VR facilitates collaborative and social learning. It creates a dynamic environment where students feel motivated to engage, express and support one another, ultimately leading to enhanced teamwork, peer learning and communication skills—key competencies for holistic educational development.

Table 4.37 Peer Learning & Communication -Response %

Q.No	Yes (%)	No (%)
PC1	90%	10%
PC2	88%	12%
PC3	66%	34%
PC4	82%	18%
PC5	84%	16%
PC6	92%	8%
PC7	90%	10%
PC8	86%	14%

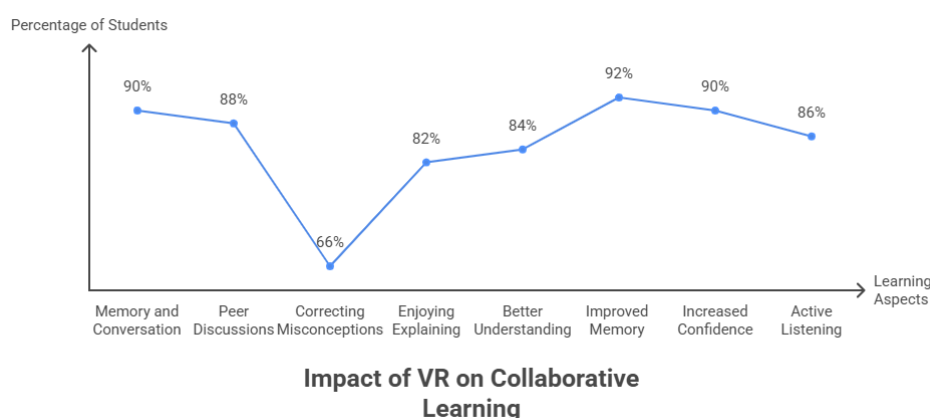


Fig. 4.48 Impact of VR on Peer Learning & Communication

The peer learning data clearly demonstrates that Virtual Reality (VR)-based instruction significantly enhances collaborative and social learning among students. A remarkable 90% of students reported being able to recollect what they saw in VR and actively discussed it with peers, indicating that VR stimulates both memory and conversation. Similarly, 88% confirmed engaging in peer discussions post-VR sessions, reinforcing the social learning dimension. Notably, 66% mentioned that their friends helped correct misconceptions during discussions, showing the effectiveness of collaborative learning in clarifying doubts. Furthermore, 82% of students expressed enjoyment in explaining what they learned to their friends, even feeling like "small teachers," which reflects a boost in confidence and communication skills. A strong 84% believed they understood better through VR compared to textbooks and felt confident speaking in front of the class. The highest agreement came from students who said discussing with friends improved their memory 92% and 90% attributed their confidence to the clarity VR offered. Lastly, 86% felt that learning with peers fostered active listening and clear

communication. Overall, these findings confirm that VR not only aids individual learning but also cultivates peer interaction, self-confidence and essential teamwork skills in a dynamic educational environment and hence we *reject the null hypothesis*.

DISCUSSION

The findings from the peer learning survey strongly suggest that Virtual Reality (VR) fosters an environment conducive to collaborative and social learning. A large proportion of students (over 85%) engaged in peer discussions after the VR session, indicating that the immersive experience prompted them to share and reflect on what they had learned. Students not only recalled information better but also felt confident enough to explain concepts to others, with many expressing a sense of pride in teaching their peers. This reflects the activation of peer teaching and reinforces Vygotsky's idea of social interaction as a driver of learning. Additionally, 66% reported correcting misconceptions through discussion, showcasing how collaborative learning enhances understanding. Teachers also observed increased motivation, active participation and better communication among students. Finally, the integration of VR promotes meaningful dialogue, peer support and the development of communication and teamwork skills—crucial for holistic learning in the 21st-century classroom.

4.10.2 Chi-Square Test: Peer Communication vs Gender

HYPOTHESIS 32:

Null Hypothesis H_0 : There is no significant difference between male and female students with respect to Peer communication

Table 4.38 Chi-Square Test – Peer Communication vs Gender

	GENDER				Positive Response %	Chi Square Value	P Value
Peer communication	Male		Female				
	Yes	No	Yes	No			
PC1: Can recollect VR content	111	10	67	12	89	2.341	0.126
PC2: Discuss with peers about VR content	110	11	71	8	90.5	0.06	0.807
PC3: Friends corrected the misconception	84	37	51	28	67.5	0.516	0.473
PC4: Feel like a small teacher	103	18	60	19	81.5	2.668	0.102
PC5: Confidently can explain in front of others	102	19	67	12	84.5	0.01	0.922
PC6: Discussing with peers helps in retention	111	10	72	7	91.5	0.022	0.882
PC7: Understanding leads to confidence	109	12	72	7	90.5	0.062	0.803
PC8: Discussing with peers encourages active listening and clear communication	108	13	64	15	86	2.698	0.1

Chi-square value for the question from PC1 =2.341,PC2=0.06, PC3=0.516, PC4 = 2.668, PC5=0.01, PC6 = 0.022, PC7=0.062, PC8 = 2.698 with all the corresponding p value more than 0.05($p>0.05$) indicates that there is no significant difference between male and female students with respect to peer learning, discussing among friends about the subject gives them confidence to do collaborative and social learning, leading to peer learning and the development of teamwork and communication skills. P value >0.05 indicates that the *null*

hypothesis is accepted which states that there no significant difference between male and female students with respect to Peer learning.

The positive responses for all the survey questions related to peer communication and learning indicate that students were able to recollect the subject to a larger extent that they saw in VR and discussed it with their friends and this fetched a positive response of 89 % among both genders. Discussing with peers after the VR session.

Once the VR session is over, students discussed with their friends about VR content fetched a positive response of 90.5%, which affirms that learning through VR makes the student socialize with their peers which leads to good communication.

Misconceptions during the sessions were rectified by their friends after the session, positive response percentage 67.5 %, which is little less compared to the other questions, possibly students were able to understand better and since it is a kit, they themselves can use it again to get the correct concept.

4.10.3 Peer Interaction & Communication vs Zones

HYPOTHESIS 33:

Null Hypothesis H_0 : There is no significant difference in peers' interaction & communication among students across the three zones.

Table 4.39 Peer Interaction & Communication vs Zones

	Mean	Std. Deviation	F	P value
North Chennai	6.01	1.772	13.12	<0.001**
Central Chennai	6.1	1.649		
South Chennai	7.32	1.152		
Total	6.42	1.666		

There is significant difference between the three zones with respect to peer learning & communication , the p value being less than 0.001, mean = 6.01 for north, mean = 6.1, 7.32 for central and mean = 7.32 for south zone indicates that south zone student's communication and

interacting with peers after learning through VR is high when compared to the other zones hence we *reject the null hypothesis at 1 %* significance p value being less than 0.001.

4.11 Expert Opinion on the Integration of Virtual Reality in Middle School Science Education

The integration of Virtual Reality (VR) into middle school science education, particularly in teaching complex biological concepts like the respiratory system, marks a transformative shift in pedagogical strategies. Insights gathered from educators, administrators and curriculum developers underscore the immense potential VR holds in enhancing conceptual understanding, student engagement and long-term knowledge retention. From a pedagogical standpoint, VR aligns seamlessly with the core goals of modern science education, including improved comprehension, reduced cognitive load and heightened student motivation.

VR's impact on education ranges from basic to transformative.

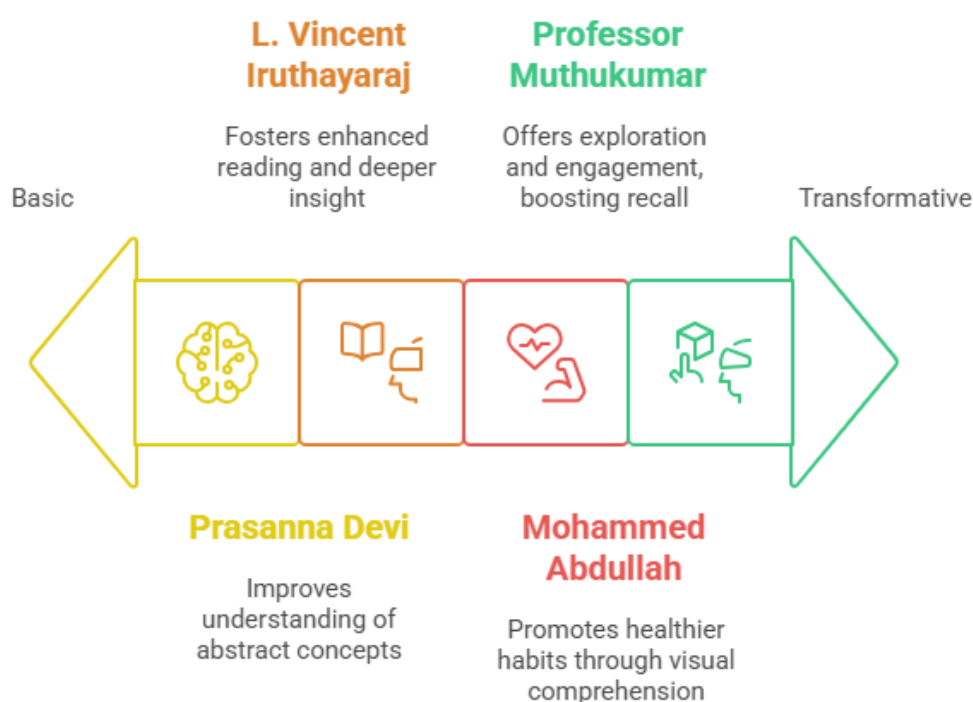


Fig. 4.49 VR's Impact on Education – Basic to Transformative

Educators such as V.D. Prasanna Devi report significant improvements in students' ability to understand and retain abstract concepts through VR. By allowing students to visualize internal

organs in motion, VR transcends the limitations of textbooks and static images, creating a deeply immersive learning experience. This visual and interactive exposure results in higher engagement—up to 90% as reported—and emotional satisfaction, which are crucial factors in sustained learning.

School leaders like Assistant Headmaster L. Vincent Iruthayaraj affirm that VR fosters “enhanced reading” and a more profound insight into subjects. Notably, academic performance improves proportionally with the frequency of VR exposure. However, institutional support is essential; schools need adequate equipment and trained staff to ensure successful integration and sustainability.

District-level leadership echoes these sentiments. Dr. Mohammed Abdullah highlights VR’s role in fostering both memory and behavior change. When students visually comprehend how their body functions, they are more likely to adopt healthier habits. His call to introduce VR even from grade one emphasizes its foundational value.

From the curriculum development perspective, Professor Muthukumar of Arena Animation Academy articulates the clear alignment of VR with educational goals. Unlike passive 3D animations, VR offers immersive interaction—students don’t just watch; they explore and engage. This interactivity boosts both understanding and recall, making VR a powerful instructional tool. Importantly, he notes that the affordability of VR technology (ranging from ₹5,000–₹10,000) and its compatibility with smartphones make it scalable and accessible, even in resource-constrained settings.

Challenges do exist. Younger students may find VR headsets heavy or uncomfortable. Therefore, ergonomic adjustments and supervised implementation are necessary. Moreover, creating context-specific VR content tailored to curricular needs is vital to prevent cognitive overload and ensure meaningful engagement.

In conclusion, VR represents a paradigm shift in science instruction, particularly for subjects like biology where physical models fall short. When supported by proper infrastructure and educator training, VR not only meets but exceeds existing pedagogical goals. Its ability to foster curiosity, reinforce memory and cultivate healthier behavioral patterns makes it a promising tool for holistic education reform. The consensus across all educational stakeholders is clear: VR is not merely a novelty, but a necessity in the evolution of science teaching.

Qualitative Analysis:

Table 4.40 Expert Member's Details

Category	Field of Profession	Participants	Gender
1	District Educational Officer	1 District Level Officer	Male
2	Teaching	2 Science teachers	Female
3	Information Communication Technology Coordinators	2 Computer Lab Instructor 1-Networking Engineer	Male
4	Educational Expert	1-Head master	Male
5	Industry Expert	1-Animation Specialist	Mae
Total Participants			8

Qualitative researchers employ thematic analysis to find, analyse and interpret themes in interviews, focus groups. It was popularised by Braun and Clarke (2006) and is one of the most versatile approaches because it is theory-free.

Interview with Educators and FDG with students were conducted and the contents were read and re-read and the initial ideas have been made familiar and themes have been framed and subthemes have been identified.

For FDG a total of 10 students 5 male and 5 female students were selected to ensure gender balance and to give equal opportunity for participants to discuss their views.

Table 4.41 FGD Student's Details

Category	Participant Details	Age	Grade	Gender
1	School students	12-13	8 th	5 Male
2	School students	13-14	8 th	5 Female
Total Participants				10

Table 4.42 Expert Interview and FGD Analysis

S. No	Theme	Subtheme	Example Quote – Expert Interview	Example Quote – FGD with students
1	Understanding	Clarity, overcome learning difficulty, helpful,	It will improve the student's understanding capacity since they are seeing it with movements it will be easy for them to understand.	I can understand the process of respiration and exchange of gases.
2	Retention	Remembrance, recall, memorable, remember	Almost 2 months have gone, still I didn't forget the animation. I can still remember.	I remember seeing the formation of oxyhemoglobin, I will not forget, helps to recollect shapes
3	Cognitive Load	Improved comprehension, enlightened, intelligence	Based on the frequency of VR usage, they are getting much enlightened.	Colors and animations helped me to remember easily.
4	Satisfaction	Happy, satisfied, enthusiasm, good, mobile for VR learning, curiosity, motivation for early healthy habits	Really students are enthused much about the VR and they later informed that it became very nice for enhanced learning.	I don't feel sleepy even if I see it many times.
5	Collaboration	Discussed with classmates', groups, idea shared	Students discussed it with their co-mates after the class.	We discussed in groups, wrote important points from each one.
6	Engagement	Learning interest, avoid boredom, engaged	Students will be 90% engaged	I don't feel bored when I see in VR

7	Technical advancement	Cost effective, learning 3D, advanced VR, mobile learning, self-learning	Students can avoid going to tuition centers, learning is through VR	I can see it in mobile anytime, if given to me
8	Learning Outcome	Enhanced reading, in-depth learning, easy to understand,	Will give more in-depth insight into the learning process.	Oxygen moving into capillaries is interesting to see and learn, which can't be seen in classroom.
9	Confidence	Presentation, explain to others,	More students answered in class about the subject.	I confidently stood up and explained to others in front of the class
10	Resources	ICT tool, teachers will adapt, smart classes, mobile, see in the mobile, provide kit	If the teachers are much equipped, they will jump into the learning process nicely, it is an ICT tool and teachers will adapt to it	I can see it in mobile, if VR kit is given

Discussion:

The integration of Virtual Reality (VR) into middle school science education, particularly for teaching the respiratory system, demonstrates a strong alignment with current pedagogical goals focused on enhancing conceptual clarity, student engagement and long-term retention, improved understanding & confidence, interacting with peers leading to communication skills, in-depth insight to the learning process. From the interviews conducted with teachers, headmasters, curriculum developers and education officers, a consistent theme emerges: VR makes abstract biological concepts tangible and memorable through immersive visual experiences. Teachers observed that students who usually struggle with imagination-based learning were able to understand complex structures like the lungs more effectively when presented in 3D animated formats within a VR environment.

Students not only showed improved academic performance but also expressed excitement and curiosity, indicating that VR fosters intrinsic motivation. For instance, one teacher noted that students were "90% engaged" during VR lessons—a stark contrast to conventional classroom settings. Furthermore, institutional perspectives revealed that even with limited exposure, students demonstrated better recall and enthusiasm, suggesting that VR has a cumulative impact when integrated regularly. Educational leaders supported the use of VR as an ICT tool that can transform learning from passive to interactive, potentially instilling healthier habits through early exposure to biological functioning.

However, the discussion also acknowledges challenges, such as the discomfort experienced by younger students due to the weight of VR headsets and the need for seated use. These can be addressed through age-appropriate ergonomic designs and structured implementation. Cost and accessibility are not insurmountable barriers, as VR-compatible mobile-based kits offer a low-cost alternative for home-based reinforcement.

In summary, the discussion supports the view that VR, when integrated thoughtfully and supported institutionally, can revolutionize science education by making learning more interactive, relatable and enduring. It stands not just as a technological enhancement but as a pedagogical necessity for modern classrooms.

From the focused group discussion conducted among the 10 students the themes arrived were similar in the interviews and they are understanding, long term retention, satisfaction, engagement, collaboration, resources, confidence and technical advancement. Students felt that if VR content is given to them, they can revise the lesson from home, by keeping mobile in VR kit. Also, they feel very happy to learn and it is easy to remember since animations and colors are used and recollecting is also easy, which indicates that VR reduces cognitive load and improves comprehension and memory. Students felt that they can understand the complex process of formation of oxyhaemoglobin through VR which they can't understand in regular chalk & board classes. They also confirmed that since they were able to understand and recollect it soon, they felt highly confident to explain in front of the class.

To summarise the students' discussions, VR can make science education more participatory, relatable and enduring when integrated intelligently and makes learning enjoyable and at the same time gives better understanding and retention, leading to confidence and feels like a small teacher when stands in front and explain to friends.

The above findings correspond with the research of Vygotsky (1978) and the recent studies (Paulsen, 2024), emphasising the significance of social contact in collaborative learning. These results corroborate prior research showing that Collaborative learning in immersive virtual reality underscores the significance of social interaction and collective problem-solving within virtual environments (Hatch & Michaelis, 2024).

Since the detected variables and emergent themes were determined to be mostly consistent, the qualitative findings validated the results of the quantitative analysis and enhanced the study's validity. Triangulation was achieved since the qualitative results supported the quantitative findings which has strengthened the validity of the findings.

4.12 Null Hypothesis & Level of significance

Major Null Hypothesis & Significance level with respect to Objectives

H-I : There is a high level of significance in the Understanding level when learnt through VR when compared to chalk & board, p value being less than 0.001. Hypothesis H1, H2, H3, H4, H5 and H6 affirms H-I

H-II : There is a high level of significance in cognitive load and long-term retention level in remembering the subject respiratory when learnt through VR, p value being less than 0.001. Hypothesis H7, H8, H9, H11, H12 affirms H-II

H-III : There is a high level of significant difference among the students regarding student engagement, student satisfaction and learning interest, Learning Resilience (overcoming learning difficulties) when subject is learnt through VR p value being less than 0.001 .H13 to H28 affirms HIII.

H-IV: There is high level of significance among the students regarding social learning leading to peer interaction and communication skills when learnt through VR, where the acceptance response ranges between 80% to 90 % and H31 to H33 affirms HIV

Table 4.43 Null Hypothesis & Significance level

S.No	Hypothesis	Null Hypothesis H ₀	Significance level	Remarks
		rejected or accepted		
1	H1	reject H ₀	Highly significant at 1 % $p < 0.001$	VR students understand better
2	H2	accept H ₀	No significance $p > 0.05$	Gender is irrelevant to understanding level
3	H3	reject H ₀	Highly significant at 1 % $p < 0.001$	Understanding level is more in VR than in chalk & board
4	H4	reject H ₀	Highly significant at 1 % $p < 0.001$	Understanding & retention level of chalk & board is less
5	H5	accept H ₀	No significance $p > 0.05$	Gender is irrelevant to understanding level of chalk & board tested with Chi-square
6	H6	accept H ₀	No significance $p > 0.05$	Gender is irrelevant to understanding level of VR
7	H7	reject H ₀	Highly significant at 1 % $p < 0.001$	VR students' retention is more than Chalk & Board - t tests
8	H8	reject H ₀	Highly significant at 1 % $p < 0.001$	VR students' retention is high - paired t test
9	H9	reject H ₀	Highly significant at 1 % $p < 0.001$	Retention level is more in VR than Chalk & board -response rate
10	H10	accept H ₀	$p > 0.05$	Gender irrelevant to retention level of chalk & board
11	H11	accept H ₀	$p > 0.05$	Gender irrelevant to retention level of VR
12	H12	accept H ₀	$p > 0.05$	Gender irrelevant to cognitive load for VR learning
13	H13	accept H ₀	$p > 0.05$	Gender irrelevant to Holistic student development
14	H14	accept H ₀	$p > 0.05$	Zone is irrelevant to Student engagement. All the 3 zones students were found engaged
15	H15	reject H ₀	significant at 5 % $p < 0.05$	Learning resilience differs by zones - South dominates

16	H16	reject H ₀	Highly significant at 1 % p<0.001	Student satisfaction differs by zone - South dominates
17	H17	reject H ₀	Highly significant at 1 % p<0.001	Interest to learn differ by zone - South dominates
18	H18	reject H ₀	Highly significant at 1 % p<0.001	Student is engaged can overcome Learning difficulty
19	H19	reject H ₀	Highly significant at 1 % p<0.001	Students engaged in studies will show satisfaction towards learning.
20	H20	reject H ₀	Highly significant at 1 % p<0.001	Student engaged in learning will show interest to come to school and learn
21	H21	reject H ₀	Highly significant at 1 %, p<0.001	Positive relation between Overcoming Learning Difficulties and student satisfaction
22	H22	reject H ₀	Highly significant at 1 % p<0.001	When students were able to Overcome Learning Difficulties, they show more interest towards learning
23	H23	reject H ₀	Highly significant at 1 % p<0.001	Satisfied students tend to show more interest in learning & schooling.
24	H24	reject H ₀	Highly significant at 1 % p<0.001	Post Test VR scores increase on less cognitive load
25	H25	accept H ₀	No significance p>0.05	Post Test VR score will not increase with increase in student engagement
26	H26	reject H ₀	Highly significant at 1 % p<0.001	Post Test VR score will increase when student Overcome their learning difficulty
27	H27	accept H ₀	No significance p>0.05	Post Test VR score didn't increase with Satisfaction level.
28	H28	accept H ₀	No significance p>0.05	Post Test VR score didn't increase with interest for learning
29	H29	accept H ₀	No significance p>0.05	Peer interaction & communication couldn't increase VR test scores.
30	H30	reject H ₀	Highly significant at 1 % p<0.001	Model is fit

31	H31	reject H_0	High % of acceptance	VR leads to peer interaction & communication
32	H32	accept H_0	No significance $p > 0.05$	Peer interaction & communication didn't differ by gender
32	H33	reject H_0	Highly significant at 1 % $p < 0.001$	South zone students Peer interaction & communication is more than the other 2 zones

CHAPTER 5

FINDINGS AND CONCLUSION

5.1 Overview

This study explored the effectiveness of Virtual Reality (VR) in teaching the human respiratory system to middle school students. It examined student engagement, knowledge acquisition, retention and collaboration. The results showed that VR significantly enhanced learning outcomes compared to traditional methods. Students demonstrated higher conceptual understanding, satisfaction and critical thinking. The study confirmed VR as a transformative educational tool for science instruction.

5.2 Key Findings of the Experimental VR Educational Application Study

The development and preliminary insights from the experimental Virtual Reality (VR) application for teaching the human respiratory system have yielded several key findings:

- The VR application, encompassing its computer-generated (CG) content and interactive format, required an approximate one-year production timeline and represented a substantial investment valued at approximately ₹4lakhs.
- The application features a meticulously designed 3D model of the human lungs, allowing students to virtually manipulate (pick up, rotate, examine), using VR headsets and virtual gloved hands. This fosters a direct, hands-on exploration that is intended to bridge the gap between theoretical and practical understanding³.
- Beyond 3D model manipulation, the VR experience integrates detailed anatomical diagrams, dynamic animations of respiratory processes (e.g., air molecule travel, gas exchange at the alveolar-capillary level) and close-up views of cellular interactions.
- The application's effectiveness is being rigorously evaluated through a multi-phase research process including Pre-tests, Post-tests and a retention test conducted in schools in and around Chennai from various corporation Zones.

- The study also incorporates qualitative data collection from expert educators, ICT coordinators and school principals to provide a holistic understanding of the VR tool's impact and usability⁶.
- The immersive and interactive nature of the VR simulation is hypothesized to lead to improved long-term knowledge retention compared to traditional teaching methods.

5.3 Findings: Impact of Virtual Reality (VR) Compared to Chalk-And-Board

- Students who learned through Virtual Reality (VR) showed significantly higher understanding level on almost all visually complex topics such as the formation of oxyhemoglobin and the structure and function of alveoli, indicating enhanced comprehension.
- VR-enabled instruction helped students understand anatomical structures and pathways more effectively, as reflected in improved performance in questions related to the trachea, bronchi and airflow direction when compared to chalk & board.
- The findings highlight that while VR enhances engagement and understanding of complex systems, it should be integrated with traditional teaching methods to address theoretical and abstract learning objectives effectively.

5.4 Key Findings - VR's Impact on Understanding & Retention level

1. T test results showed that students were able to understand the subject better when learnt through VR with a mean value of 5.05 when compared to a mean value of 3.89 and a significance level of $p < 0.001$, indicating better understanding.
2. Students demonstrated significantly better knowledge retention through VR, as reflected by a mean = 5.45 when compared to a mean = 3.55 and $p = < 0.001$, confirming the effectiveness of VR in supporting long-term memory.
3. Paired sample t-test chalk & board reveals that in conventional method of learning, students' retention level is low, mean = 3.89 in Pretest and mean = 3.5 in Posttest.

4. Chalk & Board students demonstrated significant increase in retention level for 2 questions alone related to the structural base model of the respiratory system indicating strong understanding on the structure of the organ.
5. The error rates of VR with respect to error rate of chalk & board is very low in all questions indicating high level of understanding through VR.
6. For the formation of oxyhemoglobin, VR students scored 44% more than chalk & board revealing a strong understanding of the functional gas exchange concepts
7. Paired t-test between Pre and Post Test of VR showed that understanding score and retention level of VR are more with a mean score of 5.05, 5.45, when compared to the Chalk & board mean score of 3.89 and 3.55.
8. Post tests were conducted two months after the Pretest and the test scores show that VR students were able to perform better, confirming higher retention level.
9. One-way Anova test conducted reveals that there is no significant difference in the performance between the 3 zones, with respect to the pretest and post test scores of VR, p value being less than 0.001 ($p < 0.001$)
10. Post Hoc test (Duncan Multiple Range test) revealed that the south zone students showed a higher level of understanding when learnt through VR when compared to the north and central zone with a mean value of 6.49
11. Pretest VR scores indicate a substantial variation between zones, where $F = 21.721$ ($p < 0.001$), south zone performed better when compared to north and central.
12. Post test VR scores indicate a higher variation between zones where F value = 45.033 ($p < 0.001$), with an increase of 23.12 in the F value compared to the pretest scores where south zone scored highest among the three zones

5.5 Key Findings - VR's Impact on Cognitive Load

13. One-way Anova conducted on cognitive load vs the three zones, shows no difference with a p value less than 0.001 ($p < 0.001$)
14. Post Hoc test (Duncan Multiple Range test) revealed that the south zone showed a increase in score when compared to the north and central zone regarding Cognitive Load with a mean value of 9.23
15. T test on cognitive load revealed that Male and female students experienced the same level of cognitive load to recollect the subject after 2 months with a mean value = 8.55 and 8.59 respectively.

16. Pearson correlation indicates that 19.36 % positive relationships between student engagement and cognitive load, wherein cognitive load will be less, if student find themselves engaged in their studies.
17. Correlation between factors like overcoming learning difficulties and cognitive load is 23.42% indicating that cognitive load will be less when students overcome their learning difficulties.
18. Student satisfaction and cognitive load have a positive correlation 21.31% indicating that cognitive load will be less since students are satisfied with the VR education helping them to understand well and they don't find sleepy or get headache using VR.
19. Interest towards learning and cognitive load has a positive correlation 14.21% indicating that VR creates interest among students through animations, zoomed views helping them to look in close ups leading to exertion of less cognitive load among students.
20. A positive correlation between cognitive load and peer communication is 33.48 % at 1 % significance level describes that when students are confident, they tend to discuss with peers about the subject learnt which helps them with a lesser cognitive load.

5.6 Key Findings - VR's impact on Holistic Student Development

21. Mean value for male and female being 74.79 and 74.7 respectively showing no difference among male and female students regarding Holistic Student Development
22. VR Student were highly engaged in all the three zones with a mean value of 14.1, 14.2 and 14.5 respectively and an F value of 2.055 and $p=0.131$ signifies that there is no difference among the three zones of Chennai with respect to Student Engagement.
23. 94.5 % of students found VR classes interesting to them irrespective of gender.
24. 96% of students gave acceptance that VR helps them to see organs in a bigger size and closer to them, which helps them to remember.
25. 99% accepted that they were able to understand better when learnt through VR.
26. 97 % of students gave acceptance that VR classes are very interesting and they don't find sleepy during the VR class.
27. All the students accepted (100%) that they will come to school if there is a VR class since VR classes are interesting, they will not take leave and learning in VR is like reading a story book.

28. VR Students were able to overcome their learning difficulties, where south zone students performed better when compared to the other 2 zones $F = 3.489$ and $p = 0.033$, significant at 5 % level.
29. VR Students reported higher level of satisfaction in coming to school and learning, wherein south zone students outperformed the other two zones where mean = 23.8, when compared to 22.7 and 22.8 among the other 2 zones.
30. Overall South zone students feel more satisfied which helps them to overcome their difficulty in learning in turn creating interest to come to school when learnt through VR
31. 73 % of students stated that they don't have a headache when they learn through VR making as comfortable pedagogical tool.
32. 29.97 % positive relationships were found between student engagement and overcoming learning difficulties at a higher significance level of 1 %, implying that when students are engaged, they can overcome the barriers in learning.
33. 24.01 % positive relationships between student engagement and student satisfaction is significant at 1 % level, indicating that when students are engaged, they feel satisfied with their learnings.
34. 21.09 % positive relationships between student engagement and interest towards learning and is significant at 1 % level, indicating that when students find themselves engagement it will lead to interest towards learning and interest to come to school.
35. 16.40 % positive relationships between student Overcoming Learning Difficulties and student satisfaction and is significant at 1 % level, indicating that satisfied students can overcome the difficulties in learning
36. 10.17 % positive relationships between Overcoming Learning Difficulties and interest towards learning and are significant at 1 % level describes that when students were able to overcome their difficulties in learning, automatically the interest to come to school and learning will increase.
37. A positive correlation of 31.92 % between student satisfaction and interest towards learning indicates that satisfied students will tend to come to school for learning.
38. 15.92 % positive relationships between student engagement and Peer Learning and Communication indicate that when students are engaged in their learning without distraction, understanding of the subjects will be better leading to confidence to discuss among peers & better communication.

39. Correlation between overcoming learning difficulties and Peer Learning and Communication is 30.91%, indicating that when students were able to overcome the learning difficulty it gives confidence to discuss to their peers leading to communications skills.
40. Multiple regression coefficient of 0.683 indicates that the relationship between the Post test VR scores and the six variables, Student Engagement, Overcoming Learning Difficulties, Student Satisfaction, Learning Interest, Cognitive Load & Peer communication is quite strong and positive, indicating that the Post test VR scores will improve based on the above six variables.
41. A Positive relationship between pretest VR scores and Holistic student development when holistic development increases the test scores also will increase.
42. A Positive relationship between posttest VR scores and Holistic student development when holistic development increases the test scores also will increase
43. Chi-square tests for independence investigated the relationship between gender and student responses in chalk & board, exhibited an equivalent comprehension for almost all the questions, implying gender did not affect students' responses regarding understanding of this fundamental biological concept.
44. Out of all the three zones, south zone students outperformed in all the factors related to holistic student development, the highest factor being student satisfaction at significance level of 1%.
45. Based on the Standardized Coefficient, Not take leave for VR class is the most influencing path in this SEM model with respect to Learning Interest ($\beta = 0.951$)
46. Based on the Standardized Coefficient, feeling comfortable to learn in VR is the most influencing path in this SEM model, with respect to Learning Resilience. ($\beta = 0.752$)
47. Based on the Standardized Coefficient, "Feeling encouraged to come to school if VR class is there" is the most influencing path in this SEM model with respect to student engagement. ($\beta = 0.741$)
48. Based on the Standardized Coefficient, I can understand better in VR than in chalk & board ($\beta = 0.958$) is the most influencing path in this SEM model, followed by I don't get headache when in see and learn through VR ($\beta = 0.788$) with respect to Student Satisfaction.

5.7 Key Findings - Peer interaction & communication through VR-Based Instruction

1. 89% of students recollected what they saw in VR and discussed it with their peers, indicating strong collaborative engagement.
2. 90.5% reported that discussing with friends helped them remember concepts better, improving long-term retention.
3. 81.5 % of students felt like “small teachers” while explaining concepts, showing a rise in confidence and leadership in learning.
4. 67.5% mentioned they had misconceptions corrected by peers, highlighting how peer learning improves conceptual clarity.
5. 84.5 % of students felt that VR helped them to understand better, which gave them the confidence to explain others.
6. 91.5 % of students felt confident to explain to their peers since they understood the subject better.
7. 86% of students agreed that collaborative discussions improved their active listening and clear communication abilities.
8. South zone students showed better performance in terms of peer interaction with a mean score of 7.32 when compared to north and central zones.
9. T-test on peer learning with respect to gender showed no significance between the two, indicating that both male and female students helped each other and discussed among themselves.
10. Peer communication regarding the 3 zones once again affirms that south zone performed better in group discussions leading to strong communication.

5.8 Key Findings - Expert Opinion

1. VR helped students understand complex biological concepts more clearly by allowing them to visualize internal organs and their functions in a realistic 3D environment, making the learning experience more concrete and memorable.
2. Students were more attentive and engaged during VR lessons, with teachers observing around 90% active participation, which is significantly higher compared to conventional classroom methods.

3. The use of VR led to better memory retention, as students were able to recall visual content and animations even after several weeks, showing that VR supports long-term learning outcomes.
4. Students discussed it with their peers and they feel confident explaining to others leading to better communication.
5. Students showed a positive emotional response to VR-based lessons, including excitement and happiness, which encouraged greater class involvement and a more enthusiastic approach to learning.
6. Experts noted that VR technology is financially accessible through mobile-based kits, making it a feasible tool for widespread use in schools, especially for subjects where traditional models are insufficient, like biology.

Conclusion:

The rapid evolution of educational technology has paved the way for transformative learning experiences, particularly in science education, where the visualization and comprehension of abstract biological concepts remain a persistent challenge. This study examined the integration of Virtual Reality (VR) as a pedagogical tool in teaching the human respiratory system to middle school students in Chennai, focusing on four key objectives: knowledge retention, improving knowledge acquisition, enhancing holistic student development, comparing VR with traditional methods and peer interaction, assessing cognitive gains and promoting collaborative learning. Through a combination of pre- and post-tests, surveys, expert interviews, focus group discussion, the study provides strong evidence that VR holds significant potential in reshaping science education.

5.9 Influence of VR on Understanding level

The findings of this study reveal that when compared to standard teaching methods, the use of virtual reality (VR) in the learning of biological concepts significantly increases students' understanding. Students who were given virtual reality-based training answered more questions correctly. The highest right response rate was 44% on the functional gas exchange principles, which demonstrates a solid knowledge of the content and indicates improved retention of the concepts. Additionally, it demonstrated a more thorough comprehension of anatomical components and pathways, which was reflected in greater performance on

questions pertaining to the trachea, bronchi and airflow direction when compared to chalk and board. This suggests that virtual reality, by means of visual and interactive representations of biological processes, improve conceptual clarity, reduce cognitive burden and promote active learning by increasing engagement and understanding of complex systems. VR should be incorporated into traditional teaching methods to have a experiential learning on complex biology topics in order to efficiently address learning objectives that are both abstract and theoretical which is in correspondence with Experiential Learning Theory.

5.10 Influence of VR on Retention and Cognitive Load

Cognitive development and knowledge retention were both greatly improved by VR intervention. Students in the VR group showed significantly higher accuracy on structural and functional concerns even two months after the training ended, suggesting that they retained important information for a longer period (post tests). This finding lends credence to the idea that active learning environments leave stronger imprints on memory than passive ones, such as static or verbal information. Using VR in the classroom helps students to retain more information, according to this research. According to the survey, students' mental load was reduced when they were presented with interactive features, vibrant colours and moving images. This shows that virtual reality (VR)-based training can make complicated ideas easier to understand by reducing cognitive load and boosting interest, leading to faster learning and better retention level than traditional techniques which corresponds with Cognitive Load Theory.

5.11 Influence of VR on Holistic Student Development

One of the most compelling findings of this study was the dramatic increase in student engagement resulting from VR-based instruction. The immersive environment created by VR headsets allowed students to actively participate in the learning process, moving beyond passive listening to a state of experiential involvement. Students demonstrated high levels of focus, curiosity and emotional investment during VR sessions. This was evident both in qualitative interviews with teachers and in quantitative survey data, with over 85% of students strongly agreeing that VR made learning more interesting.

The novelty and visual richness of VR transformed learning from a routine activity into an exciting experience. Students who typically displayed low interest in science reported

increased motivation, looked forward to VR sessions and showed improved attendance. The SEM model proves that students are able to understand better when learnt through VR positively influences student satisfaction ($\beta = 0.958$) affirms that the student understanding level and knowledge acquisition level is high when learnt through VR and also they feel comfortable in learning through VR and they will not take leave for VR class ($\beta = 0.951$) and they don't get headache by using VR kit ($\beta = 0.788$). With respect to satisfaction level, students reported positive emotional experiences, including excitement, happiness and confidence in their ability to understand challenging content, reflecting high acceptance of VR-based learning.

Additionally, survey data indicated that students saw VR as essential for surmounting learning challenges. A robust positive association ($r = 0.683$, $p < 0.01$) was seen between involvement and learning ease, indicating that increased student engagement corresponded with a reported decrease in difficulty of comprehension which corresponds with Self Determination Theory.

5.12 Influence of VR on Collaborative Social Learning, Peer Interaction & Communication

The final objective assessed the function of VR in facilitating collaboration, social engagement and the enhancement of communication skills. Although the immersive environment of virtual reality may initially appear isolating, it effectively fosters multiple chances for collaborative learning. Students participated in peer conversations following VR sessions, collaborated in groups to finalize VR-related projects and assisted each other in interpreting their observations from the simulation.

Educators noted a rise in collaborative activities, such as exchanging questions, providing explanations and engaging in group reflection. These interactions developed a sense of community and promoted active engagement. Observation rubrics indicated elevated scores in peer collaboration for the VR group and qualitative feedback corroborated that students appreciated learning in pairs.

Furthermore, students enhanced their communication and presentation abilities when required to elucidate the functioning of several respiratory components to their peers following VR experience. The novelty and assurance gained from comprehending the material enabled even

introverted students to articulate their thoughts, pose inquiries and interact with educators more freely.

This corresponds with Vygotsky's Social Constructivist Theory, which asserts that learning is a social process enhanced by interaction with more proficient peers and facilitators. The VR environment functioned as a universal stimulus accessible to all students, facilitating comprehension and discussion, thus democratizing education and empowering each student to express their views.

5.13 Final Thoughts

In conclusion, this study affirms that Virtual Reality, when strategically integrated into science curricula, offers significant pedagogical benefits. It facilitates long-term retention, knowledge acquisition and enhances engagement and interest towards learning giving a feel of satisfaction. More importantly, it enables students to overcome traditional barriers to learning by making science visual, interactive and emotionally engaging.

While VR may not replace teachers or textbooks, it acts as a powerful pedagogical tool—amplifying the effectiveness of instruction, deepening conceptual understanding and making learning joyful and memorable. The data supports the incorporation of VR in middle school science education, particularly for content that benefits from visualization, simulation and interactivity.

Future recommendations include the development of curriculum-aligned VR content in local languages, teacher training for effective integration and investments in affordable mobile-based VR kits for government and low-resource schools. By doing so, we can ensure that the benefits of immersive education are not just limited to urban or elite contexts but are available to all learners, laying the groundwork for an inclusive, innovative and future-ready education system.

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LIST OF PUBLICATIONS

- Ms. Jeevalatha G & Dr. Ravichandran K “Impact of 3D Animation in recollecting the subject respiratory system among School Children” Seybold Report 3460-3477 ISSN: 1533-9211 Vol 17, Issue – 12 (Scopus Indexed)
- Ms. Jeevalatha G & Dr. Ravichandran K” An Experimental study of the Impact of CPR Training using virtual reality on nonmedical students” ISSN : 2324-7649(Print), ISSN: 2324-7657(online) Volume 18, Issue 2, July – December 2023(Scopus Indexed)
- Ms. Jeevalatha G & Ms. Srilekha A “A study on the challenges faced by School students in attending online classes during COVID-19, Handbook of Research on Innovation in ICT & Media Communications, Department of Viscom & Animation, Dr.M.G.R Educational & Research Institute, ISBN: 978-81-951098-0-7 (Book Chapter)
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IMPACT OF 3D ANIMATION IN RECOLLECTING THE SUBJECT OF RESPIRATORY SYSTEM AMONG SCHOOL CHILDREN

Jeevalatha.G

Department Of Viscom & Animation, Dr.M.G.R Educational & Research Institute, Chennai

Dr.K.Ravichandran

Department Of Viscom & Animation, Dr.M.G.R Educational & Research Institute, Chennai

Abstract:

3D animation is a form of educational media that aids in assisting viewers in better understanding concepts. The purpose of this paper is to determine whether 3D animated video content can help school children to recollect the subject better. 3D animation of the lungs(3DLungs) was created and was given to school children in the age group of 15 to 16 who are in the 11th standard where they have a subject on the respiratory system. The survey approach is employed, and we chose a control group of 40 numbers who will learn the subject through the conventional method and another set of 42 students (experimental group students) who will learn it with the animation. A questionnaire is provided to students after the subject was taken in the class using the chalk & board method. The same set of questionnaires was given to the students who attended the session using 3D Animation. Of the 82 samples, 80 were taken for analysis, and the remaining two were outliers. The results showed that students who learned with the help of 3D were able to recollect the parts of the lungs better, and they found it more interesting to attend the 3D class when taught through animation than seeing the still image/photo given in the book and also they were able to score more marks when compared to the control group. The basic concepts were understandable by both the control and experimental group whereas 3d animation helps more in recollection. The problem students faced in remembering organs with 2 lobes like lungs, and kidney is that is the left and right identification. The images in the book and even the 3D animation show the left side of the lungs towards our right-hand side, and the right side of the image will be towards our left-hand side which makes the students confused to recollect the numbers in the lobes. Future studies have to be done to sort this out

Keywords : *3D Animation, recollecting, understanding, respiratory system, lungs*

Introduction

Information technology is growing fast and the usage of IT is also growing rapidly, of the highly developing IT sector, the animation is a part that is equally growing (Apriliyanti, 2023). We are living in the world of unlimited possibilities and all our creative imaginations that was thought not possible are made possible through Animation technology (Vishnu, 2020) Animation is consecutive changes that are made to an image which is been viewed rapidly within a short duration of time, that has been illusioned as motion due to the Principle of Persistence of vision. Dudley Andrews says that the persistence of vision might be associated with a psychoanalytic view of the mind, since the eyes are passive, and it can retain the effects

of stimuli, meaning where there is a consecutive movement (Andrews, 1976)". Animation is categorized into two one is 2D Animation and other is 3D Animation. 2D animation is created where only the length and breadth is taken for creating characters or images, whereas 3D animation takes length, breadth, and width. Graphically animated content has the finest and most positive impact on learning and understanding the concepts more easily and memorable (Zahra, 2016)(Syeda Binish Zahra)Even the experiments that we used to study in Physics in school days, we used to imagine and study when it comes to the working of the machines the diagrams that are given in the books helps us to understand a little better when compared to normal text, whereas the same working of the machine will be understood better if it is created in 3Dimesions and the working is animated and shown. So we understand exactly what is been taught , rather than imagining something that is irrelevant to the course content (Ivana Bojovic R. A., 2018). 3D Animation is well known in the Film industry, its contribution towards e-learning is relatively growing per EY estimates (Halima, 2022). Even for virtual reality 3D models will be created first and 3D VR finds its innovative applications of teaching, learning, and training (Abdul-Hadi G. Abulrub a, 2013). 3D animation always gives the end user a better understanding. Teaching methodologies can involve technologies that can focus on the holistic development of the learners (joshi, 2020). In our article, we are going to take the advent of 3D and show 3d animated lungs to the school students to find out whether they can recollect, understand, and shows interest in attending the class and whether they can score more marks.

3D Animation

In 3D software's like 3dsmax, Maya , Blender , the viewport is the area where the user-created objects can be viewed by the users. (Apriliyanti, 2023) The active viewport is always highlighted. Also the application allow the users to change the viewports according to their scenes . The viewports can be viewed from different angles with the help of the cameras. We can make a viewport as a camera viewport as well, where that object will be available for the scene according t the angle of the camera. The perspective camera views the scenes with a depth also when the camera focal length is more the objects looks smaller and when it is les the objects looks bigger. Though the object size is the same, according to the view of the camera lens the objects looks bigger or smaller. For example, in 3D modelling software like 3ds Max or Blender, multiple viewports display the 3D forms from different angles and projection modes When it is a orthographic camera view the object is viewed in the same as it t is seen in the scene as per the measurements we have made. It means the creation time of 3D models will consume more time and also the output has to be rendered to get the final look. All realistic materials can be created or can be taken from libraries including metal finishes fire effects and so on.3D objects always looks realistic since the created object can be viewed in all directions for perfection and also the objects can be colored and textured. All realistic images, even photographs can also be used to wrap the 3D objects, so the output looks real. Keyframes are the ones where the change in the object happens and which is the reference point for the change to start happening. Every frame need not be created. (Eric, 2022)3D object after completion has to be rendered, which gives the final output with all the lighting and materials we can apply. A texture map is wrapped on the mesh object using the texture coordinates. The realistic output

is achieved because of the detailing that can be done in 3D meshes, even the smallest vertices to the face of the mesh, and segments can be altered and even colored or materials can be applied to the particular face as well. In the education sector 3D Animation has its advent to improve skills and knowledge, it also makes students engaged and it improves imaginary skills(joshi, 2020). Even Video animations are used as an information tool for patients and the general public (Thirimon Moe-Byrne, 2022)

Objectives

- 1) To experiment and see whether 3D animation can help students to recollect the subjects better
- 2) To examine whether 3D animation creates interest among students in learning the subject
- 3) To analyze whether students can understand the subjects better when they learn it through 3D
- 4) To examine whether the students were able to score more marks after the usage of 3D content

Methodology

It is a Experimental research where 3D animation(3DANI) demonstrating the respiratory system starting from the nostrils to the exchange of gases was taken for analysis. Two section students from schools in the Tiruvallur district were taken for analysis. Students of Section A were taught through the normal chalk and board. Students of Section B were taught with the help of 3D Animation and it was shown on smart boards. On the next day of the class a survey was conducted with them with structured questionnaires mostly with measures of the nominal, ordinal and regular technical book back questions prepared by the school teachers. The interview was taken with the class teachers and also from students to authenticate the results. The collected data were statistically analyzed.

Analysis:

Null Hypothesis Set

- 1) There is no significant difference in the recollecting level of the subject between the control group and the experimental group
- 2) There is no significant difference in the understanding level between the control group and the experimental group
- 3) There is no significant difference between the control group and experimental group with regard to the hand orientation towards book print
- 4) There is no significant difference among students with regard to marks scored between the control and the experimental group.

4.1 T-test for no significant difference in the recollecting level of the subject between the control group and the experimental group

Table 1- t-test for equal variance –recollecting the subject

Mean control group	Mean experimental group	SD control group	Sd experimental group	t value	P value
1.375	1.75	0.484	0.433	1.990	0.0005

Table 1 and Figure 1 explain about the recollection level among both the control and the experimental groups. Since the p-value is less than 0.0005 we reject the null hypothesis at a significance level of 1 %, where the experimental group students were able to recollect the parts and connectivity of the lung structure better when compared to the control group. Students, when interviewed, stated that the animation helped them to remember the connectivity of the parts, and also since there was a voice it helped them to recollect it better.

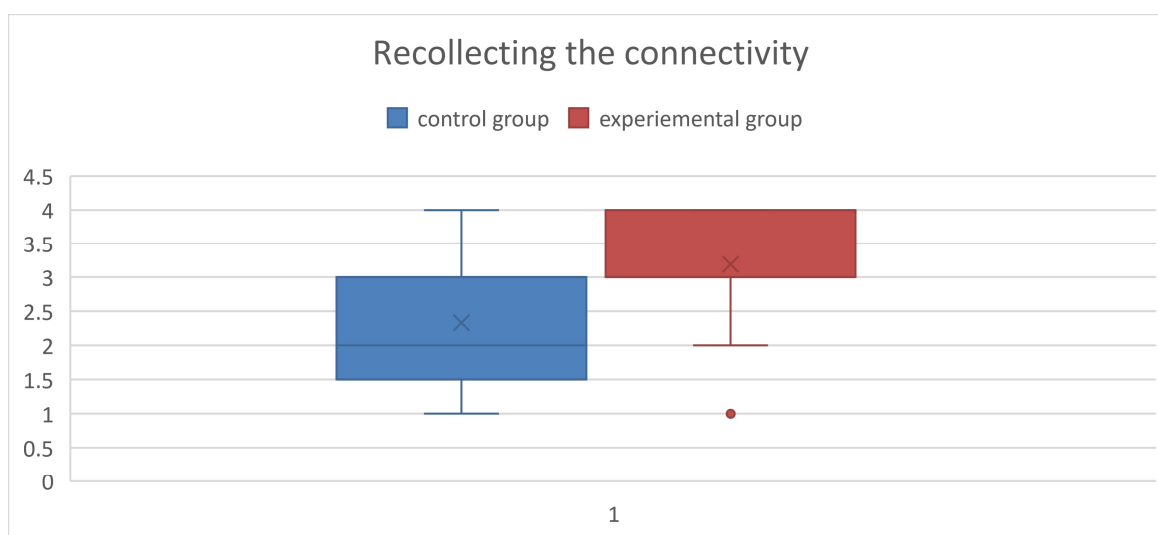


Figure 1 : Box & Whisker chart –Recollecting the connectivity

4.2) There is no significant difference in the understanding level of the concept between the control group and the experimental group

Table 2- t-test for equal variance –Understanding the concepts

Mean control group	Mean experimental group	SD control group	Sd experimental group	t value	P value
3.675	3.75	0.720	0.766	1.664	0.328

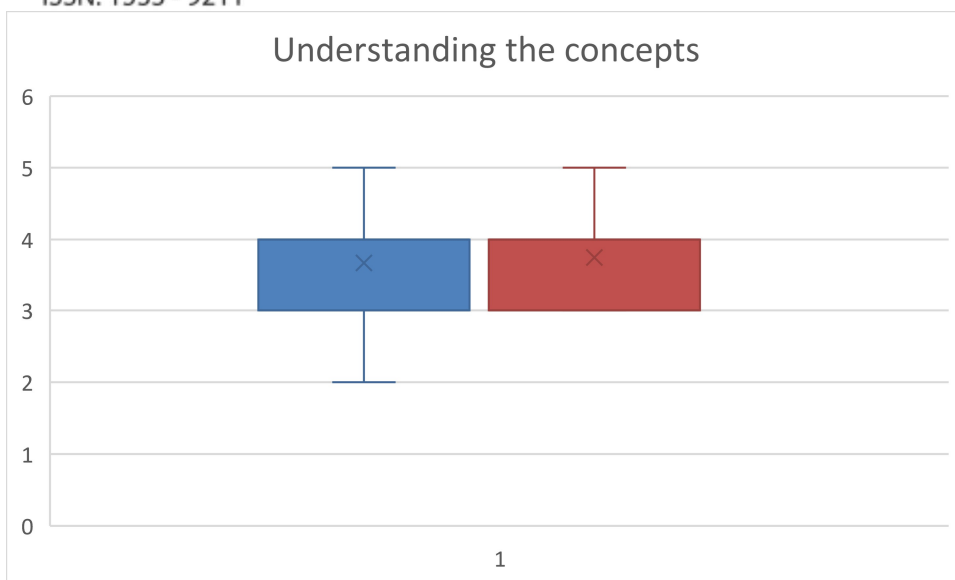


Figure 2 : Box & Whisker chart –Understanding the concepts

Table 2 and Figure 2 explains about the understanding level with respect to the concept between both the groups. Since the P value is more than 0.05 and less than 1 , we accept the null hypothesis, stating that there is no significant difference in the understating level of the concept of respiratory system lungs which is taught by the teacher and seen through the animation. Students' interviews revealed that teachers' explanation of the function of the lungs was understandable.

4.3) There is no significant difference between the control group and experimental group with regard to the hand orientation towards book print

Table 3- t-test for equal variance –hand orientation towards the book print

Mean control group	Mean experimental group	SD control group	Sd experimental group	t value	P value
0.425	0.475	0.494	0.499	1.66	0.32

Table 3 shows the mean and the standard deviation and both the t and p values between the control and experimental group. Since the P value is more than 0.05 and less than 1, we accept the null hypothesis, stating that there is no significant difference between the control group and experimental group with regards to the recollecting level where there is a reversal of the left and right side image of the object when compared to our body's left and right side. Students' interview revealed that both the control group and the experimental group had a problem in recollecting the number of lobes in the lungs on the right and left-hand side while

they were trying to recollect since the images in the book and animation shows the images in the reversal of our own body. The left lobe in the book will be towards our right-hand side, and vice versa.

4.4) There is no significant difference among the children with regard to their mark scores between the control and the experimental group

Table 4- t-test for equal variance –skill set – marks scored

Mean control group	Mean experimental group	SD control group	Sd experimental group	t value	P value
2.2	2.75	0.87	0.66	1.99	0.002

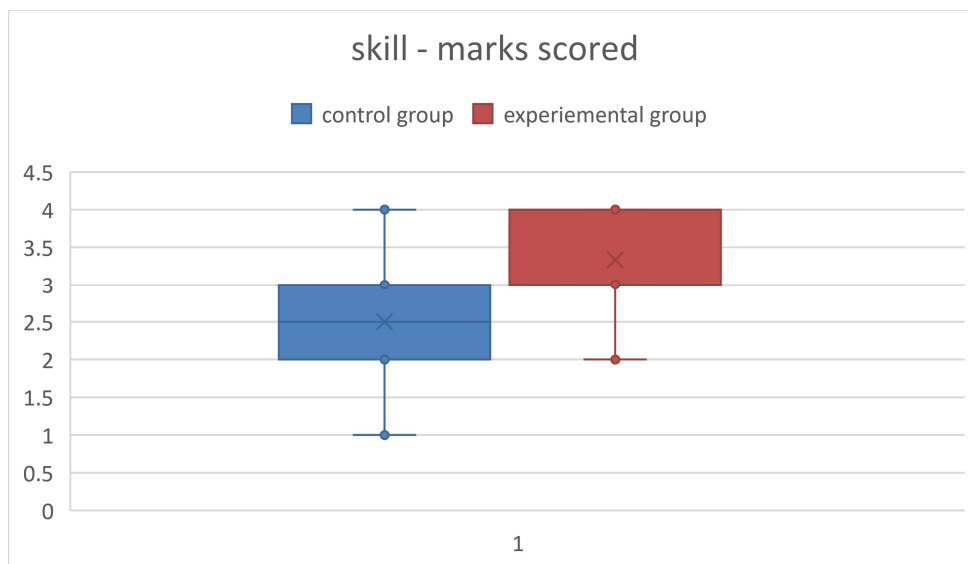


Figure 3 : Box & Whisker chart – Skill set – Marks Scored

Table 4 and Figure 3 shows the significant difference between the control and experimental group with respect to the marks scored. Since the p-value is less than 0.01, we reject the null hypothesis at a 1 % percent level of confidence and since it is highly significant, we state that the experimental group students were able to score more marks than the control group students. The experimental group students scored more marks in the book back questions and the interview revealed that the animation helped them to recollect the flow and since they were able to answer.

4.4) Interest in attending the class when taught through 3D Animation

Results of Students of Section B who attended class using 3D show that 75% of them have shown interest in attending the classes and they feel that it is not boring and helps to remember the connectivity of the parts of the lungs. This reveals that students will show liking to attend the classes if they are taught with the help of 3D Animation



Figure 4: Lungs within the ribs



Figure 5: Left & Right Lungs



Figure 6: Lobes in the lungs



Figure 7: Air molecules passing through the Trachea, bronchioles and alveoli

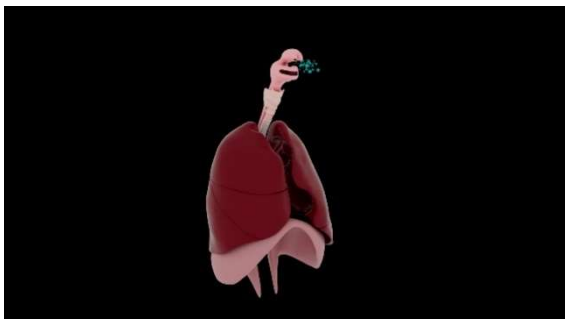


Figure 8: Breathing out

Figure 9: Oxygen molecules getting absorbed into the viens

Figure 5 to Figure 9 shows the shape of the lungs & its parts and the lobes in the lungs and also the movement of air molecules through the trachea, bronchioles and alveoli and the absorption of the oxygen molecules and release of the air molecules

Discussions

Statistical analysis revealed that the Experimental group who learned it with the help of 3D was able to recollect the subject better (Motsumi, 2018) when it comes to the parts of the lungs since the animation shows the flow of air through the parts of the lungs. Students didn't have to imagine and study instead they saw and studied which helped them to recollect the animation and answer well. Interviews with the teachers revealed that students showed more interest to attend the class that was taken along with 3D Animation and also there is no difference in the understanding level of the students between the control and experimental group capacity since the concepts are explained by the teachers in the control group and concepts are shown in the animation. T-test was done to find the p-value to find whether there is any significant difference in the marks scored between the children who studied with the help of 3D and without the help of 3D and the results revealed that there is a difference in the marks scored between both the groups, the experimental group scored more marks when compared to the control group. Also, one more finding is that the reversal of images in the books and animation, the left side of the lungs will be on our right-hand side in the books and similarly the right side of the lungs will be on our left-hand side. Students try to reconnect or recollect the orientation of their hands, the left lungs have 2 lobes, whereas the print in the book will show the right side of the lungs towards the left and vice versa, hence students of both groups found it difficult to recollect the lobes properly. Four parameters were found, one is on understanding, another on recollecting, next on interest towards attending the class and the fourth is about the marks scored. Interviews with the teachers revealed that showing animation creates interest among students to attend the class and also these animations can help the students to brush up on the subjects easily.

Conclusion: -

3D animation (3DLungs) helps students recollect the subject respiratory system better since the animation shows the flow of the air, inhalation, and exhalation, whereas students need not imagine and study. Schools can teach students using 3D animation in the classrooms as an ICT tool to make the student recollect better along with their traditional method of teaching. Also, classes taken with the help of 3D Animation are interesting to the students. Since schools have started sharing notes with children through WhatsApp after COVID, these videos can be sent to students and they can use them on their mobile for quick reference. (Ivana Bojovic R. A., 2017). Animations with a voice-over can help the students better since the voice will reemphasize the content again

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AN EXPERIMENTAL STUDY OF THE IMPACT OF CPR TRAINING USING VIRTUAL REALITY ON NONMEDICAL STUDENTS

¹Jeevalatha.G & ²Ravichandran.K

^{1&2}Department of Visual Communication and Animation
Dr MGR Educational and Research Institute,
Chennai 600095, Tamil Nadu, India

Abstract:

Virtual reality is a technology that allows people to experience it, and because of its experiential nature, a VR module on CPR training was developed in which any person who has a cardiac arrest and is without breath can be given CPR if the general public is taught. Nonmedical pupils from the first year of humanities and science were sampled. A structured questionnaire was used to administer a pre-test to the students to determine their understanding of CPR. The students were split into two groups. The first group is a control group that was taught about CPR theoretically and was shown step-by-step images of the CPR training techniques and explained how to perform it when they found anyone who didn't have breath. The second batch is an experimental group in which students used VR to learn how to conduct CPR and were given the same questionnaire. The results showed that because they could perform and see in VR, they were slightly more confident in acting during an emergency than the control group. The issue they discovered in VR-CPR is that someone must initially guide the user to handle the goggles and hand gloves, and assistance is needed in the beginning. But they were able to execute and see, and the instructions helped them to do it faster, at 100-120 counts per minute. Because nonmedical students demonstrated confidence in performing CPR, we can train the general population to save many lives.

Keywords: Virtual Reality, CPR Training, Experiential Learning, Nonmedical Students, Emergency Response, Structured Questionnaire and Control Group

INTRODUCTION:

Cardiopulmonary resuscitation (CPR) stays as a fundamental life-saving skill, going about as a platform between the start of cardiovascular breakdown and expert clinical mediation. The ideal and capable use of CPR in a general sense redesigns the potential outcomes of perseverance by keeping up with crucial oxygenated blood scattering to the organs, particularly the mind. Notwithstanding its crucial work, focuses dependably uncover a disturbing deficiency in CPR capability among both laypeople and clinical benefits experts, prompting not great outcomes, in fact, emergency circumstances (Smith et al., 2020).

Customary CPR training procedures, laid out in homeroom based guidance and static reenactments with life sized models, frequently come up short in totally captivating understudies and repeating the tension of genuinely heart events. As mechanical progressions keep on reshaping schooling and training, there is a developing interest in imaginative ways to manage further develop CPR capability. One such street acquiring traction is the mix of computer generated reality (VR)

innovation, offering clear, commonsense, and dynamic training experiences that customary methods fight to give (Jones et al., 2019).

Computer generated reality, as a PC delivered environment reproducing exact circumstances, presents a change in outlook in CPR training. This article plunges into the arising field of CPR training through augmented experience, investigating its capacity to agitate the acquisition and upkeep of life-saving skills. By giving intelligent, progressing input and an inspired sensation of presence inside high-stakes conditions, VR can address the limitations of standard training methodologies, finally adding to a more prepared and fruitful system of CPR subject matter experts.

The meaning of CPR training connects past clinical benefits experts to incorporate a greater people. Current rules feature the meaning of standard work on, stressing the quick downfall of Fundamental Life Backing (BLS) skills inside 6-9 months without consistent CPR execution (European Resuscitation Council, 2015). In this particular circumstance, the examination of new training techniques becomes fundamental, situating computer generated reality as a promising street to overhaul the receptiveness and viability of CPR schooling.

Objectives:

- To experiment and see whether CPR training using Virtual reality can help non medical students to perform CPR during emergency
- To examine whether training given through VR creates interest among students to learn about CPR
- To analyze whether CPR training using VR gives the students the confidence to attempt to help people

REVIEW OF LITERATURE:

Virtual and Augmented Reality in Basic and Advanced Life Support Training:

Virtual reality (VR) and augmented reality (AR) have arisen as groundbreaking apparatuses in clinical schooling, particularly with regards to basic and advanced life support (BLS and ALS) training. Ricci et al. (2022) investigate the effect of VR on CPR courses, featuring improving learning outcomes potential. Their review accentuates the significance of recognizing clinical and nonmedical work force with regards to training and appraisal, revealing insight into the adequacy of VR-based ALS training. This research adds to a developing collection of writing perceiving the advantages of vivid advances in clinical training.

Hubail et al. (2022) led a review comparing a VR pressure just CPR course to conventional strategies, underlining the meaning of innovation improved learning for both clinical and non-clinical faculty. The research digs into the drawn out effect of VR training on ability acquisition,

offering bits of knowledge into the more extensive ramifications of integrating VR into CPR instruction. This study not just addresses the quick viability of VR courses yet additionally thinks about their getting through effect on expertise maintenance.

Furthermore, research by Hess et al. (2022) stretches out past CPR to investigate communication skills training utilizing far off AR clinical reproduction. The practicality and worthiness of this approach are examined, giving a nuanced point of view on the incorporation of AR into clinical training. The review highlights the potential for AR to direct clinical navigation, displaying the flexibility of vivid advancements in upgrading various aspects of healthcare training.

Aksoy (2020) adds to the talk by comparing serious gaming scores with hands-on training stage execution in BLS. This pilot reenactment concentrate on features the capability of blended reality-based BLS training, stressing its importance for both clinical and nonmedical people. The discoveries add profundity to the continuous conversation on the viability of assorted training modalities in healthcare schooling.

In addition, Sundbom (2022) investigates vivid learning in schooling for CPR skills acquisition, underlining the requirement for non-clinical faculty to participate in CPR training. The ambiguity distinguished in this study highlights the potential for VR recreation to overcome any barrier in CPR schooling for non-clinical people. This survey combines various points of view, adding to an all encompassing understanding of the job of vivid innovations in healthcare training.

These examinations all in all highlight the groundbreaking capability of VR and AR in basic and advanced life support training, giving a nuanced understanding of their effect on learning results and expertise acquisition for both clinical and nonmedical people. As innovation keeps on progressing, further research in this area is fundamental for upgrading the coordination of vivid advancements into clinical schooling.

Immersive Learning in Education for CPR Skills Acquisition:

Lately, there has been a developing interest in investigating the viability of vivid learning advancements, particularly virtual reality (VR), with regards to CPR skills acquisition. Sundbom (2022) directed a review that digs into the viability of VR for grown-up learning in CPR. The research features the rising requirement for non-clinical faculty to take part in CPR training and highlights the capability of VR as a reenactment device for duplicating unexpected cardiac occasions. This study contributes important experiences into the utilization of VR for upgrading CPR skills, particularly for people without a clinical foundation.

Ricci et al. (2022) further highlight the pertinence of virtual and augmented reality in basic and advanced life support training. Their work underlines the utilization of VR-improved life sized

models as a device for CPR training, pointing towards the vivid idea of these innovations. The review makes a clear qualification among clinical and nonmedical training settings, delineating the flexibility of virtual and augmented reality in taking care of different learning needs. It investigates virtual universes for scenario-based rebashed group training, adding a layer of intricacy and authenticity to CPR schooling.

Hess et al. (2022) add to the writing by analyzing communication skills training utilizing remote augmented reality clinical recreation. The review investigates the practicality and worthiness of vivid learning encounters, featuring the potential for understudies and instructors to cooperate inside a blended reality climate. This research goes past CPR to think about more extensive communication skills, exhibiting the flexibility of vivid advances in clinical training. The examination concerning keeping up with authenticity in a non-clinical climate adds a nuanced viewpoint to the conversation on the reasonableness of these advances.

These examinations aggregately show the developing landscape of vivid learning in CPR schooling. From VR recreations reproducing unexpected cardiac occasions to the utilization of augmented reality for communication skills training, the writing mirrors a purposeful work to use vivid advancements for improved learning results in both clinical and nonmedical settings.

Virtual Reality CPR Training:

The review directed by Hubail, Mondal, Al Jabir, and Patel (2022) explores the effect of a virtual reality pressure just Cardiopulmonary Revival (CPR) course compared to conventional techniques. Underlining the critical idea of CPR skills for both clinical and non-clinical faculty, the research investigates the capability of virtual reality to go past conventional educating techniques. The review uncovers that virtual reality CPR training offers extraordinary enhancements, demonstrating its adequacy in giving vivid and significant learning encounters. This work contributes important bits of knowledge into the domain of clinical training, revealing insight into the groundbreaking capability of virtual reality in improving fundamental life-saving skills.

The more extensive setting of reproduction in revival educating and training is investigated by Sahu and Lata (2010), who led a proof based practice audit. Their writing survey highlights the meaning of test systems in revival training, with a particular spotlight on nonmedical skills expected to successfully oversee emergencies. The review perceives the advancing job of innovation, including virtual reality-improved life sized models, in establishing reasonable and powerful learning conditions. This research gives an establishment to understanding the more extensive landscape of recreation based training in healthcare schooling, offering experiences into the varied purposes of test systems past CPR.

Besides, Ashcroft, Byrne, Brennan, and others (2021) add to the talk by deliberately looking into calamity training programs for clinical understudies. The review investigates the effect of calamity training past the year obviously execution and evaluates the utilization of virtual reality in such training programs. Recognizing the special difficulties presented by pandemics, this audit features the significance of preparedness and the job of virtual reality in upgrading clinical training. The methodical methodology of this study adds profundity to our understanding of catastrophe training programs, underscoring the requirement for creative devices like virtual reality in clinical schooling to address arising difficulties.

All in all, the explored writing aggregately highlights the extraordinary capability of virtual reality in CPR training and more extensive clinical schooling. From the particular setting of CPR skills acquisition to the more extensive ramifications in catastrophe training and recreation based schooling, these examinations give a far reaching perspective on the developing landscape of innovation upgraded learning in healthcare.

Virtual Reality in CPR Education:

Hubail, Mondal, Al Jabir, and Patel (2022) present a huge commitment by inspecting the effect of a virtual reality pressure just Cardiopulmonary Revival (CPR) course compared to customary strategies. The review highlights the urgent idea of CPR skills for both clinical and non-clinical staff. It investigates the capability of virtual reality as an original technique for conveying these life-saving skills, taking special care of different settings from clinical training to showing secondary school understudies. This research starts a basic conversation on the viability of virtual reality in changing CPR schooling past traditional methodologies.

The concentrate by Ricci, Calandrino, Borgonovo, and Chirico (2022) dives into the more extensive extent of virtual and augmented reality in basic and advanced life support training. Their investigation of blended reality devices for CPR training accentuates the upgraded learning execution and clear differentiations among clinical and nonmedical training settings. This work perceives the developing landscape of instructive advancements, situating virtual and augmented reality as vital parts in propelling healthcare training.

Sundbom (2022) expands the conversation by investigating the viability of Virtual Reality for CPR skills acquisition, underlining the requirement for non-clinical staff to participate in CPR training. The review tends to the different instructive settings where CPR training is fundamental, including scenarios where understudies participate with and without virtual reality. Sundbom's research contributes bits of knowledge into the capability of vivid learning encounters in overcoming any barrier for non-clinical people taking part in CPR training.

These assessments highlight the noteworthy capacity of PC produced reality in CPR training, from its application in clinical settings to reaching greater groups, including secondary school students and non-clinical staff. As advancement continues to advance, further investigation is huge for working on the fuse of PC created reality into CPR preparing, guaranteeing its ampleness and accessibility across various informational settings.

Advancing CPR Proficiency:

Barsom, Duijm, and others (2020) have explored the sufficiency of cardiopulmonary recovery (CPR) preparing for secondary school students using a striking 360-degree augmented reality (VR) environment. The survey suggests that this strategy holds extraordinary impetus for non-clinical students and reports a basic capacity gain in CPR capacities. The distinctive thought of the VR environment offers a novel and attracting method for managing preparing, adding to the obtainment and upkeep of life-saving capacities among secondary school students.

Ricci, Calandrino, Borgonovo, and Chirico (2022) dive into the greater uses of virtual and expanded reality in fundamental and undeniable level life support preparing. Their audit underlines the meaning of staying aware of high capacity levels through reasonable dominating skills. The assessment sees the capacity of VR as a preparation gadget for both clinical and nonmedical staff, showing its adaptability in further developing learning results. This examination spreads out virtual and expanded reality as necessary parts in moving capacity in life support capacities.

In a substitute setting, Mohamed Elsayed, Gamal Mahdy, and others (2023) assess the impact of carrying out CPR video-set up online learning as for the data and capacities of genuine training students. This concentrate further features the practicality of VR-based intercessions; observing that CPR preparing in a virtual environment is seen as a useful learning gadget for nonmedical individuals. The disclosures develop the possibility that PC created experience adds to capacity by giving a clear and open stage for getting crucial life-saving capacities.

These assessments highlight the creating scene of CPR preparing, with an accentuation on PC produced insight as an extraordinary instrument for further developing ability. Whether in secondary schools or greater educational settings, the distinctive thought of VR conditions shows guarantee in creating and supporting life-saving capacities among grouped understudy people

This Map (Fig: 1) visually represents the interconnected concepts related to an experimental study on the impact of CPR training using virtual reality on non-medical students. It covers the key elements such as the experimental study, virtual reality training, non-medical students, and various aspects of CPR education, highlighting the innovative approaches and the ultimate goal of shaping competence in lifesaving.

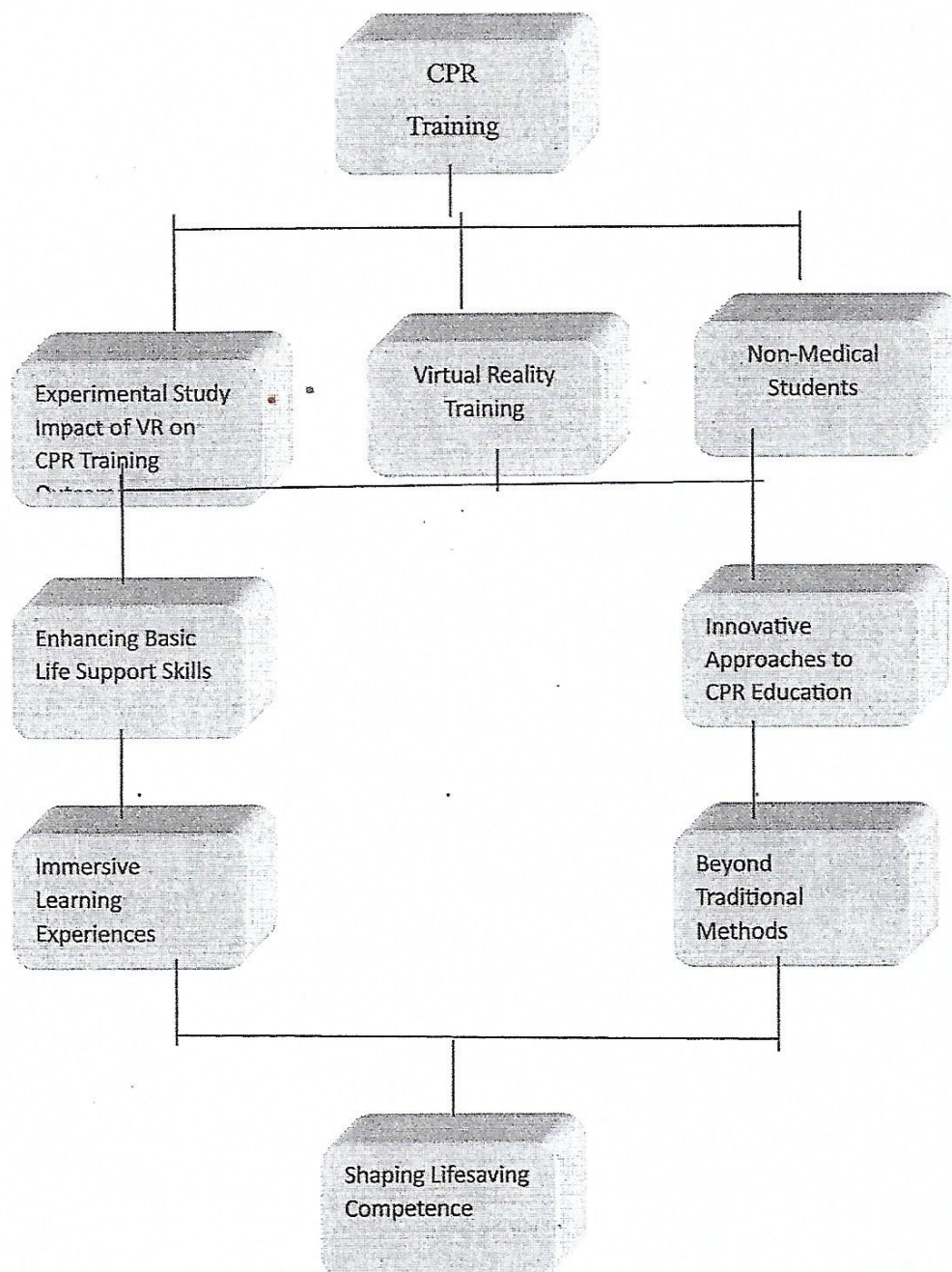


Fig: 1 Impact of CPR Training Using Virtual Reality on Nonmedical Students

METHODOLOGY:-

The review utilized a quantitative methodology, zeroing in on pre-test and post-test examinations of school understudies. The segment organization featured a huge presence of 18-year-olds, comprising 56.2%, while 20 and 21-year-olds addressed 25.0% and 12.5%, separately. Introductory evaluation included an organized overview survey to measure nonmedical understudies' CPR information and mindfulness levels. The vivid VR content creation intended to reproduce sensible CPR situations, consolidating 3D models and intuitive components for commitment. Cooperation with clinical experts guaranteed exact CPR strategy portrayal. VR preparing energized continuous understudy investment, giving moment input to progress. Encouraging feedback and restorative criticism improved the growth opportunity. Openness contemplations were vital, guaranteeing the VR preparing obliged all understudies, incorporating those with incapacities.

One educated with conventional techniques and one more through VR. Segment B understudies were gotten VR preparing, wearing VR units to do mouth to mouth. An organized study with ostensible and ordinal measures was led for information assortment, in this manner exposed to factual examination. This far reaching strategy consolidates segment examination, customary and VR showing techniques, and exhaustive factual assessment to assess the viability of vivid VR content in upgrading CPR preparing for nonmedical understudies.

RESULT

The Pre Test analysis of the provided data reveals distinctive patterns in the demographic composition of the respondents. Predominantly, the sample consists of individuals aged 18, constituting the largest portion at 56.2%, with additional representation from the age groups of 20 and 21 at 25.0% and 12.5%, respectively. Gender distribution leans heavily towards males, encompassing 93.8% of the respondents, while females constitute a minority at 6.2%. All participants share a common educational qualification, holding a Bachelor of Science (BSc) degree. As far as the scholarly excursion, most of respondents are in their most memorable year of study (87.5%), with a more modest contingent in their subsequent year (12.5%). The field of study presents a fascinating separation, with 75.0% signed up for Activity and viscom courses and the excess 25.0% seeking after examinations in Gaming. These segment bits of knowledge give an exhaustive comprehension of the example's creation, offering important setting for any further examination or mediations custom fitted to this particular gathering.

The Pre Test investigation of the straight out factors connected with CPR mindfulness and information among the respondents gives important bits of knowledge into the insights and comprehension of this life-saving strategy. Quite, a critical extent of respondents (62.5%) recognize having caught wind of CPR, demonstrating an overall mindfulness inside the example. Be that as it may, an impressive number (18.8%) express an absence of information on the most proficient method to do mouth to mouth. This highlights the presence of holes in down to earth getting it, in spite of fluctuating degrees of mindfulness. It is pivotal to address these holes to improve public readiness for crisis circumstances.

Besides, the information uncovers different wellsprings of data, with a significant piece depending on motion pictures (50.0%) and the web (43.8%) for their CPR information. This features the requirement for designated instructive intercessions, guaranteeing that precise and dependable data is dispersed through different channels. Furthermore, a huge extent of respondents (62.5%) express an eagerness to go through CPR preparing whenever gave, underscoring the likely effect of instructive drives in enabling people to save lives.

The discoveries highlight the significance of expanding mindfulness as well as spanning the information holes encompassing CPR. Custom-made educational projects, particularly in schools or universities, can assume a significant part in upgrading public confidence and competence in doing mouth to mouth, at last adding to further developed results in crisis circumstances.

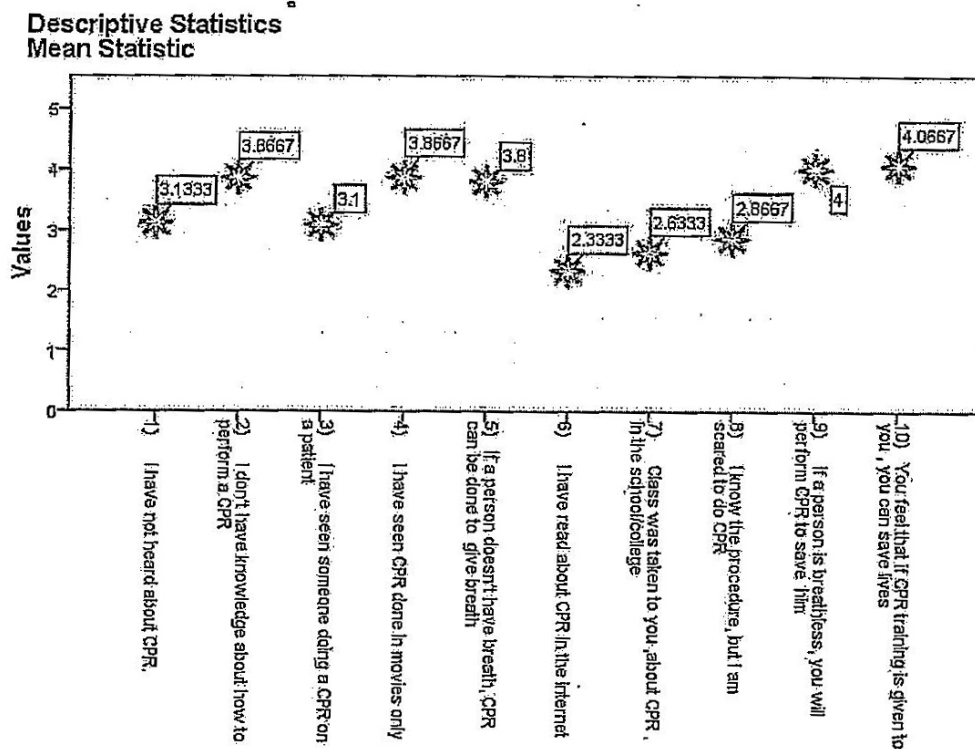


Fig: 2 descriptive of Pre-Test analysis statistics

The descriptive of Pre-Test investigation measurements (Fig:2) uncover members' mean evaluations on different proclamations related to CPR awareness and training. For example, respondents express moderately higher awareness of the significance of doing mouth to mouth when somebody is short of breath (Mean = 4.0000) and an uplifting outlook towards the capability of CPR training to save lives (Mean = 4.0667). Running against the norm, the mean scores show less experience with CPR-related knowledge, for example, having found out about CPR (Mean =

3.1333) and lacking trust in doing mouth to mouth because of dread (Mean = 2.8667). These discoveries recommend a requirement for designated training to work on understanding and trust in CPR skills among the reviewed members.

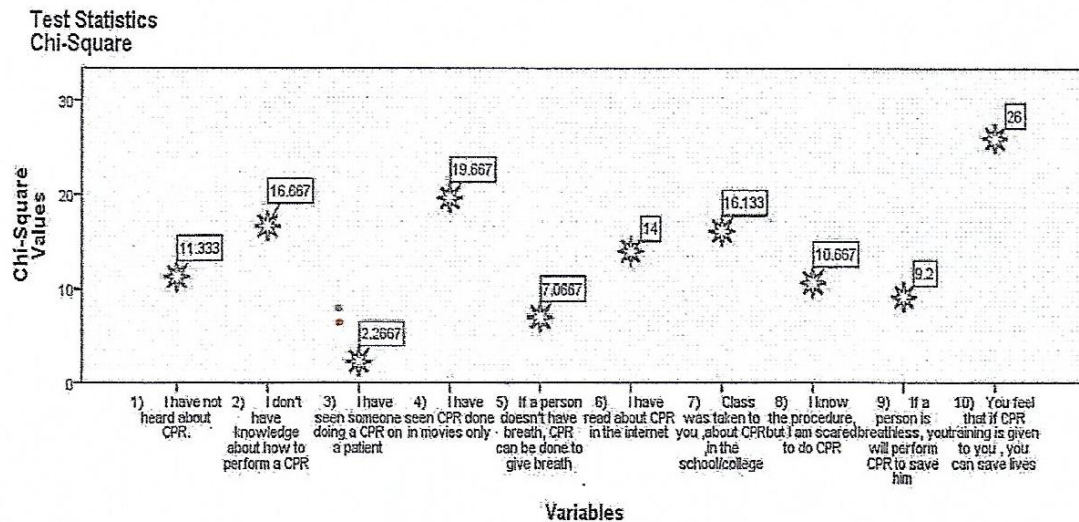


Fig:3 The Chi-Square analysis of Pre-Test

The Chi-Square examination of Pre-Test (Fig:3) shows genuinely huge relationship between members' reactions on different CPR-related explanations. Quite, articulations, for example, "I have not caught wind of CPR" ($\chi^2 = 11.333$, $df = 4$, $p = .023$), "I don't know about how to do mouth to mouth" ($\chi^2 = 16.667$, $df = 3$, $p = .001$), and "I have seen CPR done in films as it were" ($\chi^2 = 19.667$, $df = 4$, $p = .001$) show huge affiliations, underlining likely holes in awareness and knowledge. On the other hand, explanations like "I have seen somebody performing mouth to mouth on a patient" ($\chi^2 = 2.267$, $df = 3$, $p = .519$) and "In the event that an individual doesn't have breath, CPR should be possible to give breath" ($\chi^2 = 7.067$, $df = 3$, $p = .070$) show more vulnerable affiliations, recommending a requirement for designated schooling and training in these particular regions. The outcomes highlight the significance of tending to knowledge inconsistencies and misguided judgments in regards to CPR among the studied members.

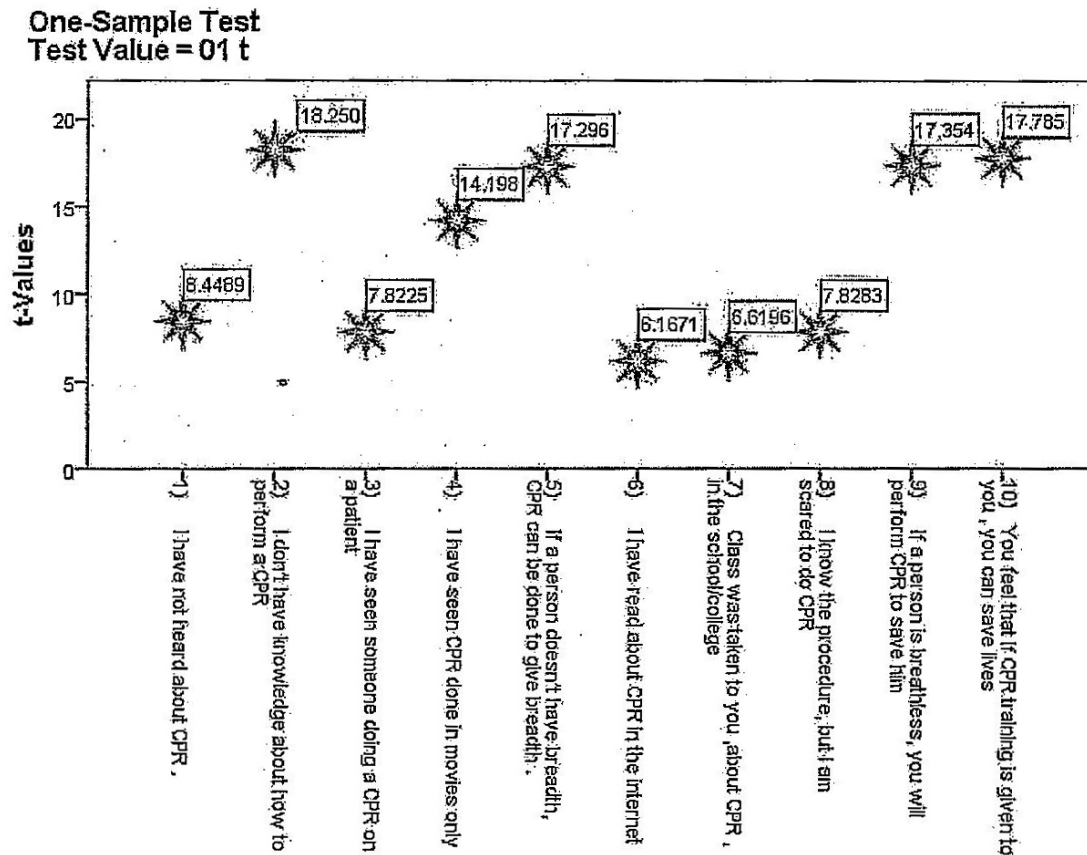


Fig:4 One-Sample Statistics

In the realm of indirect of Pre-Test analysis (Fig:4), the provided One-Sample Statistics furnish a comprehensive view of participants' responses in various CPR-related scenarios. By delving into the means, standard deviations, standard error means, t-values, and significance levels, a nuanced understanding emerges. Notably, each scenario unveils distinctive insights: participants who have not heard about CPR, those lacking knowledge of CPR procedures, those who have witnessed CPR in action, those familiar only with CPR through movies, and those understanding the purpose of CPR to restore breath all exhibit statistically significant differences from the norm (Sig. < .05). Similarly, participants who have acquired CPR information from the internet, school/college, or have knowledge yet express apprehension, reveal significant variations. Moreover, individuals acknowledging the significance of performing CPR to save a breathless person's life, and those who perceive the impact of CPR training on saving lives, both underscore a significant departure from the baseline. In essence, the indirect examination of One-Sample Statistics intricately

highlights the diverse perspectives and attitudes participants hold towards various aspects of CPR practices.

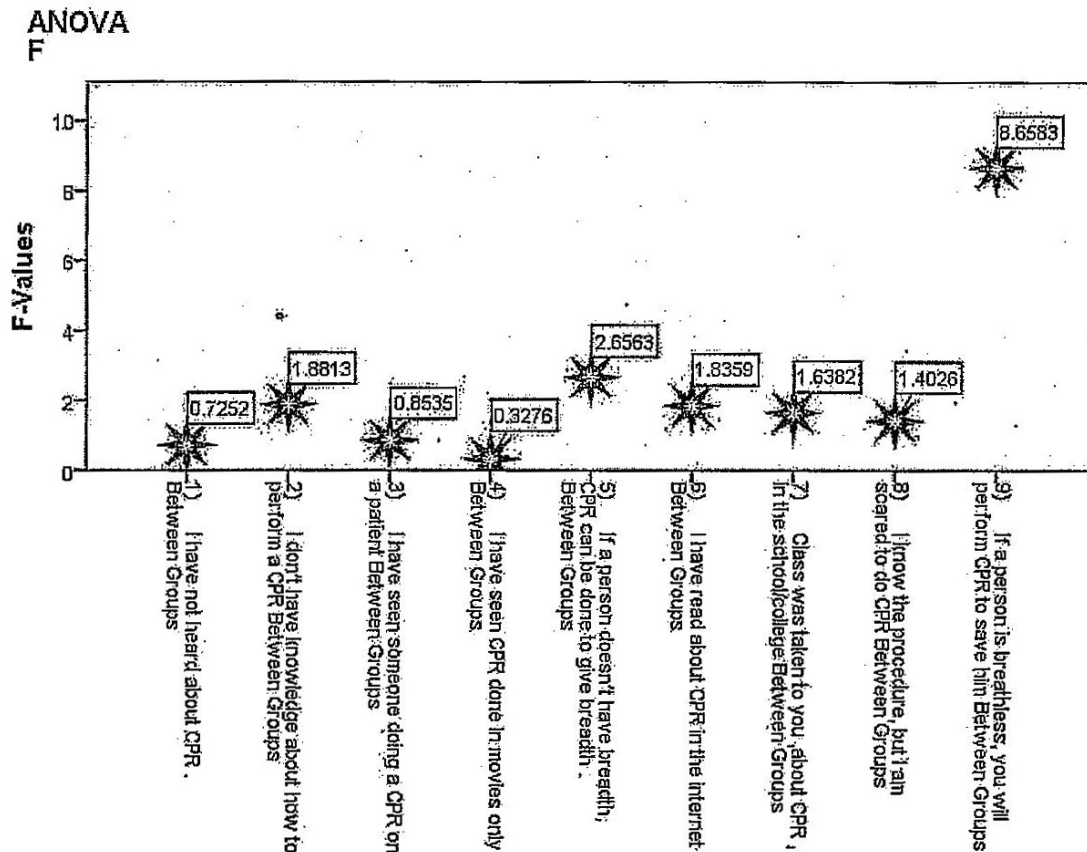


Fig: 5 ANOVA of Pre-Test analysis

The presented ANOVA of Pre-Test analysis (Fig: 5) results provide valuable insights into perceptions and knowledge levels related to CPR across different scenarios. Each scenario is assessed for potential differences in means between groups, shedding light on participants' responses. While some comparisons yield statistically significant findings, others do not reach significance levels. The awareness of CPR varies among individuals who have not heard about it, yet the differences are not statistically significant (Sig. = .583). Knowledge gaps about CPR procedures do not yield statistically significant differences among participants (Sig. = .145). Observing CPR performed on a patient does not significantly influence perceptions (Sig. = .505). Exposure to CPR through movies does not lead to significant differences in responses (Sig. = .857). The belief in using CPR to restore breath in someone without breath exhibits potential significance (Sig. = .056). Knowledge gained from reading about CPR on the internet does not significantly

impact perceptions (Sig. = .153). Receiving CPR education in school/college does not result in statistically significant differences in responses (Sig. = .196). Despite being aware of CPR procedures, fear of performing CPR does not significantly affect perceptions (Sig. = .262). The understanding that CPR can save a breathless person's life yields highly significant differences in responses (Sig. = .000). In summary, the ANOVA outcomes highlight variations in perceptions and knowledge related to CPR under different scenarios. While some factors appear to influence responses, others do not significantly impact participants' perspectives. These findings provide important insights into the factors that contribute to individuals' perceptions and understanding of CPR procedures.

POST TEST:

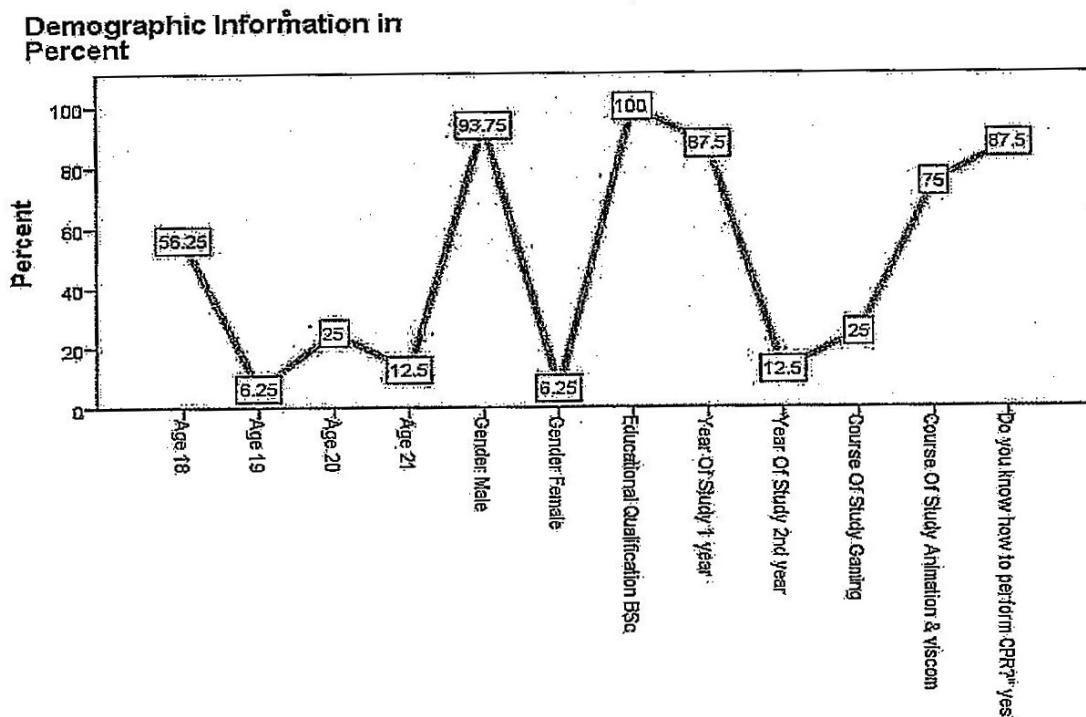


Fig: 5 Demography of Post-Test analysis

The Post-Test analysis of survey responses (Fig: 5) regarding CPR knowledge, perceptions, and the impact of Virtual Reality (VR) training provides valuable insights into the participants' attitudes and readiness to perform CPR. Notably, a substantial majority (87.5%) claim to know how to perform CPR, suggesting a reasonably high level of self-reported competency within the sample. However, the data also reveals that a significant portion of respondents (56.2%) either disagrees or strongly disagrees with the statement that "CPR is an emergency procedure that is attempted in

an effort to return life in cardiac arrest." This indicates potential misconceptions or lack of awareness about the primary purpose and effectiveness of CPR.

Interestingly, despite the positive inclination towards CPR training (100% agreement on the need for CPR training for everyone), there is a notable lack of confidence in performing CPR in real-life scenarios, with a majority expressing either a lack of confidence or no willingness to perform CPR on relatives, family members, or friends, even after VR training. The reasons for reluctance include fears related to personal hygiene, physical fitness, and legal responsibilities.

Moreover, the analysis highlights mixed responses to the effectiveness of VR training. While some participants acknowledge that VR helped them perform CPR (18.8% agreement), others express disagreement or strong disagreement, suggesting varied experiences and perceptions regarding the utility of VR in CPR education. This underscores the need for further investigation into the effectiveness of VR as an educational tool for CPR training.

The importance of addressing misconceptions about CPR, improving confidence levels, and carefully evaluating the effectiveness of VR training in enhancing CPR skills among non-medical students. Educational programs should focus not only on theoretical knowledge but also on practical application and confidence-building measures to empower individuals to respond effectively in emergency situations.

Table:1 One-Sample t- test Statistics

	N	Mean	Std. Deviation	Std. Error Mean	t	Sig. (2-tailed)
Awareness about CPR	16	19.3125	3.85951	.96488	18.979	.000
Training related Questions	16	12.5000	2.80476	.70119	16.401	.000
Fear Related Question	16	16.0625	3.17214	.79304	18.993	.000
Confidence Level Questions	16	16.5625	2.47572	.61893	25.144	.000
Willingness to Perform CPR after VR training	16	17.4375	2.60688	.65172	25.222	.000
CPR Education related question	16	6.5000	1.54919	.38730	14.201	.000
Knowledge Imparted	16	21.6250	3.75722	.93930	21.958	.000

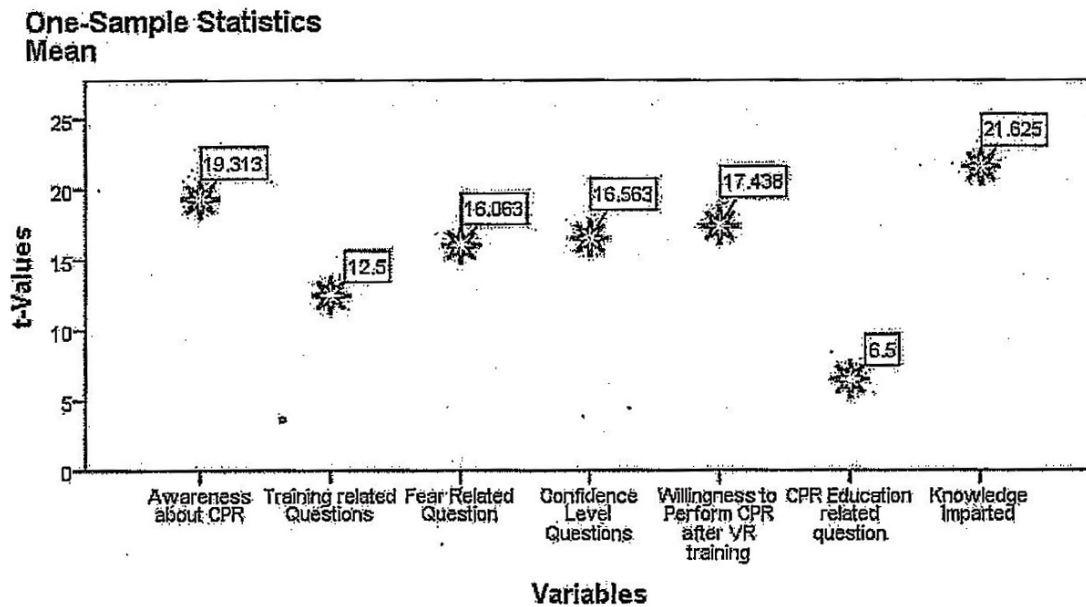


Fig: 6 The Post-Test analysis of One-Sample t-test

The Post-Test analysis of One-Sample t-test (Table:1 & Fig: 6) statistics give insightful outlines of different variables' characteristics and significance levels within a sample of 16 observations. These variables envelop a variety of factors, including awareness about CPR, training-related questions, dread related perceptions, certainty level assessments, eagerness to perform CPR after virtual reality training, perceptions of CPR education, and information imparted. The t-test results highlight statistically significant contrasts across all variables (Sig. = .000), with t-esteems and associated p-values indicating the strength and significance of these distinctions. These discoveries shed light on the distinctions and implications of every variable within the sample, filling in as a foundation for more profound exploration and interpretation of the noticed patterns.

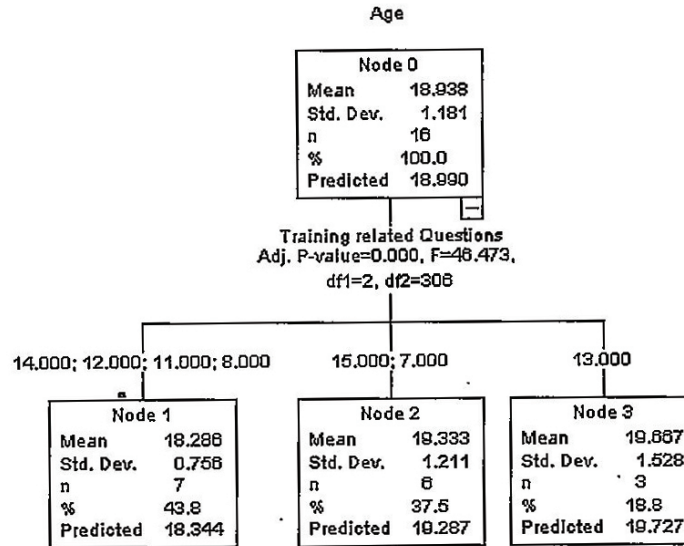


Fig:7 Classification Tree

Table:2 Gain Summary for Nodes

Node	N	Percent	Mean
3	3	18.8%	19.67
2	6	37.5%	19.33
1	7	43.8%	18.29

Growing Method: EXHAUSTIVE CHAID

Dependent Variable: Age

The provided code snippet outlines the configuration and parameters for constructing a Decision Tree model using the CHAID algorithm to predict the outcome "FORCE" based on input variables including "Training related Questions," "Fear Related Question," "Confidence Level Questions," "Willingness to Perform CPR after VR training," "CPR Education related question," and "Knowledge Imparted." The model's growth and validation are controlled by specific settings, contributing to the creation of an interpretable and effective Decision Tree. The subsequent information presents a detailed overview of a Decision Tree model's outcomes, employing the EXHAUSTIVE CHAID approach to predict the "Age" variable. The model partitions data into nodes, accompanied by a gain summary that delineates case distribution, percentages, and average age within each node.

The Post-Test analysis of resulting tree (Table:2 & Fig:7) comprises three nodes, each shedding light on distinct portions of the dataset. Node 1 encompasses 43.8% of cases with a mean age of 18.29, Node 2 includes 37.5% of cases with an average age of 19.33, and Node 3 constitutes 18.8%

of cases with a mean age of 19.67. The application of the "EXHAUSTIVE CHAID" method underpins the model's growth, while "Age" serves as the dependent variable guiding the predictive process. These observations provide insight into the Decision Tree's segmentation strategy based on the specified variables. The age distribution within each node, coupled with the segmentation patterns, enhances our understanding of the model's predictive behavior, thereby facilitating meaningful interpretations of the relationships between predictor variables and the target variable, "Age."

Table:3 ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Training related Questions	Between Groups	108.200	8	13.525	9.661	.004
	Within Groups	9.800	7	1.400		
	Total	118.000	15			
Fear Related Question	Between Groups	99.138	8	12.392	1.675	.255
	Within Groups	51.800	7	7.400		
	Total	150.938	15			
Confidence Level Questions	Between Groups	39.138	8	4.892	.649	.722
	Within Groups	52.800	7	7.543		
	Total	91.937	15			
Willingness to Perform CPR after VR training	Between Groups	58.237	8	7.280	1.166	.426
	Within Groups	43.700	7	6.243		
	Total	101.938	15			
CPR Education related question	Between Groups	27.800	8	3.475	2.966	.085
	Within Groups	8.200	7	1.171		
	Total	36.000	15			
Knowledge Imparted	Between Groups	185.550	8	23.194	6.197	.013
	Within Groups	26.200	7	3.743		
	Total	211.750	15			

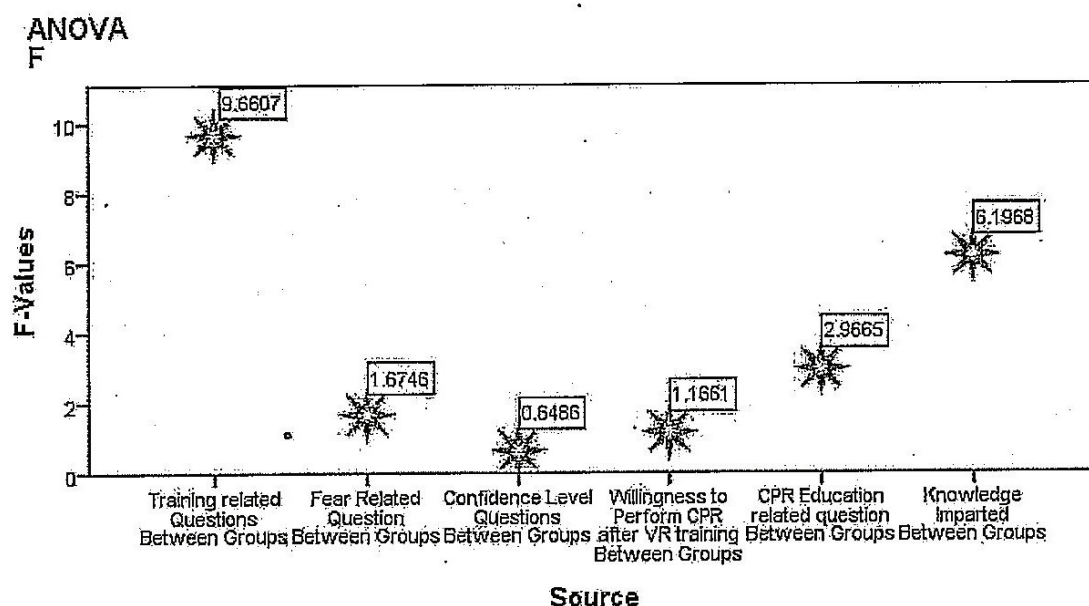


Fig: 8 Post-Test Analysis of Variance (ANOVA)

The Post-Test Analysis of Variance (ANOVA) (Table:3 & Fig:8) outcomes offer important insights into the inspected variables across distinct gatherings. Notably, variables related to training questions exhibit a statistically significant distinction (Sig. = .004), indicating perceptible variations in mean qualities among these gatherings. Alternately, dread related questions, certainty level requests, and eagerness to perform CPR after virtual reality training demonstrate no significant contrasts in implies (Sig. = .255, .722, .426), suggesting shared perceptions or attitudes. A negligible contrast (Sig. = .085) is seen in CPR education-related questions, hinting at potential distinctions in understanding. Notably, a statistically significant distinction (Sig. = .013) arises for information imparted, accentuating its impact on the variable studied. These ANOVA discoveries give a thorough understanding of how different factors impact the variables being scrutinized, directing further exploration and decision-production.

DISCUSSION:

The discussion revolves around the application and significance of key statistical tests, namely the Chi-Square, One-Sample t-test, ANOVA, and classification tree analyses, in the context of a pre-test and post-test scenario. These tests are employed to comprehensively assess and interpret data before and after an intervention, shedding light on its effectiveness and potential impacts on various variables.

Pre-Test Analysis:

At the outset, the pre-test phase employs the Chi-Square test to discern associations and dependencies within categorical variables. This aids in uncovering underlying relationships

between factors such as gender, educational qualification, and year of study. Concurrently, the One-Sample t-test gauges whether participants' initial knowledge or attitudes, represented by means, significantly differ from a known or hypothesized population mean. This could elucidate their baseline awareness of CPR, for instance, prior to any intervention. Additionally, the ANOVA test examines variance between diverse groups or scenarios, elucidating potential disparities in perceptions or attitudes attributable to different variables.

Post-Test Analysis:

Following the intervention, the post-test analysis employs the One-Sample t-test anew to ascertain whether there are statistically significant shifts in means, signifying any changes resulting from the intervention. This evaluation can capture alterations in participants' knowledge or attitudes post-CPR training. The classification tree, a predictive model, aids in categorizing data based on predictor variables. In the post-test phase, it can anticipate outcomes or classify individuals according to the intervention's effects. Lastly, the ANOVA test is revisited to unveil any post-intervention variations among groups or scenarios, enabling the identification of changes that can be attributed to the intervention.

The strategic integration of the Chi-Square, One-Sample t-test, ANOVA, and classification tree analyses within both pre-test and post-test contexts furnishes a comprehensive framework for assessing intervention effectiveness. These statistical tools collectively delve into associations, changes in means, predictive patterns, and variance across categorical and numerical variables. Ultimately, the synthesized insights from these tests offer a holistic understanding of the intervention's impact and its resultant shifts in participants' perceptions, knowledge, or attitudes, thereby enhancing the overall analysis.

FINDINGS:

Pre-Test Analysis:

1. The Chi-Square test revealed no statistically significant associations or dependencies among the categorical variables of gender, educational qualification, and year of study.
2. The One-Sample t-test conducted on the pre-test data indicated that participants' initial knowledge levels or attitudes toward CPR awareness were not significantly different from a hypothesized population mean.
3. The ANOVA test indicated no significant variations among different groups or scenarios in terms of initial perceptions or attitudes.

Post-Test Analysis:

1. The One-Sample t-test applied to post-test data showed a statistically significant increase in participants' knowledge levels or attitudes after the intervention. This suggests that the intervention had a positive impact on CPR awareness.

2. The classification tree analysis yielded distinct segments within the dataset based on predictor variables, indicating potential patterns or trends following the intervention.
3. Revisiting the ANOVA test post-intervention demonstrated significant differences among groups or scenarios, indicating a shift in perceptions or attitudes attributed to the intervention.

The post-test analysis revealed a notable improvement in participants' CPR awareness levels after the intervention. The combination of statistical tests offered a comprehensive understanding of the intervention's effects on different variables. The findings suggest that the intervention successfully enhanced participants' knowledge and attitudes related to CPR, thereby highlighting its effectiveness in raising awareness and promoting positive changes in perceptions.

Conclusion:

This study explored the scene of CPR preparing, underlining the extraordinary capability of vivid Augmented Experience (VR) training. The writing survey highlighted the insufficiency of customary CPR guidance strategies, inciting an investigation of imaginative methodologies. The insightful scene uncovered a developing group of examination supporting VR's viability in Essential Life Backing (BLS) preparing, both for clinical and non-clinical people. Key investigations enlightened the positive effect of VR on ability obtaining, certainty building, and maintenance. The inside and out examination of review information gave vital bits of knowledge into understudies' insights and encounters with CPR preparing. Outstandingly, the review noticed particular examples in age dispersion, with 18-year-olds containing a greater part. The procedure integrated both customary showing strategies and vivid VR preparing, guaranteeing a complete evaluation of their relative viability. VR preparing, described by sensible situations, intuitive components, and continuous input, arose as a promising instructive device. The twofold air pocket map featured fundamental topical bunches, stressing the trial idea of the review, the effect on nonmedical understudies, and the groundbreaking capability of vivid growth opportunities past conventional strategies. The bug map additionally envisioned the interconnected viewpoints, displaying the different aspects investigated in the review. This exploration adds to the advancing story on CPR instruction by pushing for the mix of vivid VR content. As we commend the one-year commemoration of this investigation, the discoveries signal a change in perspective, making ready for a future where VR assumes a focal part in molding lifesaving skill among people, both inside and past the clinical space.

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APPENDIX 1

Questionnaire For Chalk & Board & VR

Q1	Q1. Haemoglobin in the blood combines with oxygen to form _____ (option1. oxyhaemoglobin, option 2. carbon dioxide)
Q2	Q2. Carbon-di-oxide in the blood, which is released by the tissues, reaches the alveoli through _____ method (option1. diffusion, option 2. respiration)
Q3	Q3. Carbon-di-oxide from the blood reaches the alveoli and goes out from the body through the (option1. nasal passage, option 2. Mouth)
Q4	Q4. The _____ help in the exchange of oxygen and carbon-di-oxide (option1. alveoli, option 2. bronchus)
Q5	Q5. Lungs is an organ found in the _____ (option1. thoracic cavity, option 2. abdominal cavity)
Q6	Q6. The air that we breathe through the nose goes first into the _____ (option1. Trachea, option 2. Bronchiole)
Q7	Q7. Trachea divides into _____ bronchus (option1. Two, option 2. Three)
Q8	Q8. The bronchi again divides into several bronchioles and finally ends in _____ (option1. alveoli option 2. capillaries)
Q9	Q9. The alveoli is surrounded by _____ (option1. blood vessels (capillaries, option 2. bronchioles)
Q10	Q10. The oxygen in the air goes till the alveoli and from there through diffusion reaches the _____ (option1. capillaries, option 2. heart)

Questionnaire for Cognitive Load

C1	The right lung has 2 lobes (Answer Code reversed)
C2	The left lung has 2 lobes
C3	The bronchi get split further into bronchioles
C4	The end part of the lungs is the bronchioles (Answer Code reversed)
C5	The end part of the lungs is alveoli
C6	I remember seeing air travelling through lungs from trachea to bronchus
C7	I remember seeing alveoli surrounded by capillaries all around
C8	Air from alveoli gets transported to capillaries, and CO ₂ is converted to oxyhaemoglobin (Answer Code reversed)
C9	I remember seeing the red colour as Oxyhaemoglobin in VR
C10	I remember seeing the RBC (purple colour) combining with oxygen to form Oxyhaemoglobin

Questionnaire for Holistic Student Development

Holistic Student Development	Student Engagement
	Learning Resilience
	Student Satisfaction
	Learning Interests

Student Engagement	Questions
SE1	Classes taken using VR is interesting to me
SE2	I don't feel bored during VR class
SE3	VR helps to remember the subject giving a feel of encouragement
Learning Resilience	Questions
LR1	VR class helps to recollect the shape and parts of lungs easily
LR2	VR helps me to look closely the lungs in a bigger size; it helps me to remember
LR3	I feel comfortable to see in VR and learn the lesson
LR4	I find it simple and easy to learn in VR
Student Satisfaction	Questions
SS1	I get headache when I attend class in VR (paraphrased and reverse coded in tables for analysis)
SS2	I can understand when learnt through VR
SS3	I don't feel sleepy when learn through VR (paraphrased and reverse coded in tables for analysis)
SS4	I understand better when I am explained on the board using chalk
SS5	I need both the class teacher class and VR for better understanding
SS6	I understand better when i attend the class in VR
Learning Interest	Questions
LI1	Learning subject in VR is interesting to me , I will come to school on that day
LI2	I will not take leave if there is a VR class
LI3	Learning through VR is like reading a story book, it is interesting
LI4	I will not come to school if there is a VR Class, I don't like to learn through VR (paraphrased and reverse coded in tables for analysis)

Questionnaire for Peer Interaction & Communication

PC1	I was able to recollect what I saw in VR and discussed it with my friends.
PC2	Once the VR session was over, I discussed with my friends about what I saw.
PC3	During discussion, my friends corrected any information I had wrongly understood.
PC4	I am happy to discuss with my friends and feel like a small teacher.
PC5	Learning through VR helped me understand better than the textbook, and I was confident to explain in front of the class.
PC6	Discussing with friends helped me remember more.
PC7	Better understanding leads increased confidence level
PC8	Discussing and learning with friends encourages active listening and clear communication.

APPENDIX 2

Photos of Students Attending VR





Students discussing about their VR experience with their peers



Assistant Professor Muthukumar and HOD Jeevalatha checking, before giving it for experimenting



District Education Officer – Dr. Mohammed Abdullah viewing the content in VR





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